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CLOSURE/POST-CLOSURE GUIDANCE FOR RCRA OPEN BURNING AND OPEN DETONATION UNITS

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(Revision 1)

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EXECUTIVE SUMMARY

The U.S. Army Environmental Center (USAEC) has tasked the U.S. Army Corps of Engineers (USACE), Mobile District to prepare a generic Resource Conservation and Recovery Act (RCRA) Subpart X guidance document for closure of open burning/open detonation (OB/OD) units. Closure and post-closure plans are needed for OB/OD units pursuing a RCRA permit (i.e., the closure plans are a required part of the permit application). In addition, an approved closure/post-closure plan is needed prior to closure for those units that are not seeking a RCRA permit to continue OB/OD operations. This guidance is necessary since there is a need to consolidate available RCRA closure guidance for convenience in application to OB/OD units. In addition, munitions related waste and potential co-location with active military ranges present unique problems for the closure of OB/OD units.

The guidance will be useful for developing site-specific closure strategies, preparing closure/post-closure plans, and negotiating and implementing closure actions. This guidance also supplements the U.S. Army Open Burn/Open Detonation Unit Management Guide that provides information to support OB/OD permit versus closure decision making as well as provides tools needed for site characterization and estimating closure costs (U.S. Army, February 1999).

The closure guidance presents an overview of alternative OB/OD closure strategies. This includes the identification and discussion of various closure scenarios and significant issues. In addition, the guidance provides technical information to support the preparation of closure plans, the conduct of site investigations, and the determination of closure performance standards that are needed to develop and implement site-specific closure strategies. A companion guidance document will be available for the estimation of OB/OD closure costs.

Closure requirements and associated issues are quite complex. Therefore, it is not feasible to provide a prescriptive approach applicable for all OB/OD closures. Rather, alternative closure scenarios as well as associated closure issues are identified and discussed. Some of these issues are still unresolved and may warrant obtaining legal opinions on a case-by-case basis, and some may require revising current U.S. Army policy.

The major factors that will influence closure strategies include the following:

- Regulatory requirements
- Degree of contamination
- Cost-effectiveness of alternative closure strategies

RCRA closure regulations basically present two closure options for Subpart X units: clean closure (i.e., removal of the hazardous waste and constituents), or closure as a landfill (i.e., capping the hazardous waste and constituents that are left in place). EPA and the state regulatory agencies would ideally prefer clean closure, but they recognize that this may not be possible for all OB/OD units. For some OB and OD units, neither of the two options is satisfactory. Based on costs and contamination levels, clean closure may not be the most cost-effective strategy for many OB/OD units. Closure as a landfill may present similar problems or may be inappropriate in many

cases. Therefore it is necessary to consider a broader list of alternatives to clean closure, which include the following:

- Landfill closure (cap constructed)
- Partial closure (not all of the OB/OD units are closed)
- Risk-based clean closure (commensurate with guidance issued by EPA in March 1998)
- Delay of closure (i.e., an administrative or deferred closure)

Risk-based clean closure generally provides the greatest flexibility for the final closure of OB/OD units. However, the delay of closure approach may be beneficial for many OB/OD units located within active military ranges.

Post-closure maintenance and monitoring as well as land use restrictions may also be needed for closures with waste in place.

In addition to discussing closure issues and strategies, the closure guidance also provides the following technical information:

- Overview of OB/OD treatment of energetic wastes and the potential for residues
- RCRA closure requirements
- Design and conduct of site investigations as well as data analysis
- Determination of clean-closure performance standards
- Specification of closure plan content

In summary, user-friendly guidance for OB/OD units as presented in this document will facilitate compliance with RCRA closure requirements. The guidance will be useful for developing site-specific closure strategies, preparing closure/post-closure plans, and negotiating and implementing closure actions. However, it will still be necessary to address site-specific conditions and address the varying requirements of each lead regulatory agency.

1. INTRODUCTION

The U.S. Army Environmental Center (USAEC) has tasked the U.S. Army Corps of Engineers (USACE), Mobile District to prepare a generic Resource Conservation and Recovery Act (RCRA) Subpart X guidance document for closure of open burning/open detonation (OB/OD) units. Closure and post-closure plans are needed for OB/OD units pursuing a RCRA permit (i.e., the closure plans are a required part of the permit application). In addition, an approved closure/post-closure plan is needed prior to closure for those units that are not seeking a RCRA permit to continue OB/OD operations.

This guidance represents a compilation of regulatory information and Army-wide closure process experience that can minimize the cost of closure plan preparation. In addition, recommendations are presented for inclusion in the closure plan that have the potential for significantly reducing closure costs (U.S. Army, February 1999).

1.1 PURPOSE OF THE DOCUMENT

The OB/OD closure guidance document is intended for use by Army installations or their contractors in preparing site-specific closure/post-closure plans for Army-operated Subpart X OB/OD units. The specific objective is to develop a user-friendly guidance document for the Department of the Army (see Fig. 1-1).

User-friendly guidance for OB/OD units will facilitate compliance with RCRA closure requirements. The guidance will be useful for developing site-specific closure strategies, preparing closure/post-closure plans, and negotiating and implementing closure actions. However, it will still be necessary to address site-specific conditions and the varying requirements of each lead regulatory agency. This guidance also supplements the U.S. Army Open Burn/Open Detonation Unit Management Guide that provides information to support OB/OD permit versus closure decision making as well as provides tools needed for site characterization and estimating closure costs (U.S. Army, February 1999).

1.2 DOCUMENT ORGANIZATION

Sect. 2 of this document presents an overview of alternative OB/OD closure strategies. This includes the identification and discussion of various closure scenarios and significant issues. Sects. 3 through 9 provide technical information to support the preparation of closure plans, the conduct of site investigations, and the determination of closure performance standards that are needed to develop and implement site-specific closure strategies. Supplemental information is provided in Appendices A-J.

2. OB/OD CLOSURE STRATEGIES

Information is provided in this section to aid in the development of site-specific OB/OD closure strategies. Closure requirements and associated issues are quite complex. Therefore, it is not feasible to provide a prescriptive approach applicable for all OB/OD closures. Rather, alternative closure scenarios as well as associated closure issues are identified and discussed. Some of these issues are still unresolved and may warrant obtaining legal opinions on a case-by-case basis, and some may require revising current U.S. Army policy. The major factors that will influence closure strategies include the following:

- Regulatory requirements
- Physical location
- Degree of contamination
- Proximity to migration/exposure pathways
- Risk factors
- Cost-effectiveness of alternative closure strategies

Closure requirements for OB/OD units are defined in RCRA. However, the interpretation and application of these closure standards may vary between U.S. Environmental Protection Agency (EPA) Regions. State requirements and policies also add to this variability. Therefore, the lead regulatory agency should be contacted to determine closure requirements prior to the development of a closure strategy. In addition, negotiations associated with the regulatory review and approval process for the closure plan provide an opportunity to address installation-specific closure issues. It may be beneficial to consider building a formal "partnering" relationship with the regulatory agency in order to establish reasonable site-specific closure performance standards.

The nature and extent of residues from OB/OD operations will also be a significant closure factor. These conditions will determine the feasibility of a complete cleanup of the OB/OD unit. A combination of technical remediation limitations and associated closure costs may preclude some closure approaches. In such cases it may be appropriate to downscale closure performance standards to provide a more cost-effective closure approach which can still be considered protective of human health and the environment. Again, regulatory negotiations will be needed for acceptance of those alternative closure strategies.

Closure cost estimates are an obvious major input for evaluating installation-specific closure strategies. OB/OD closure costs have the potential to exceed a million dollars for some units. However, closure costs will vary significantly based on site conditions and regulatory requirements. Thus, the USAEC has tasked the USACE, Mobile District to prepare a U.S. Army Open Burn/Open Detonation Unit Management Guide, which includes guidance for estimating the cost of closing U.S. Army OB/OD units (U.S. Army, February 1999). It is anticipated that this guide will be utilized by Army installations in preparing site-specific cost estimates for closure of OB/OD units.

A summary of RCRA closure regulations is provided in Sect. 4 of this document. However, RCRA regulations do not specifically address many typical OB/OD closure scenarios and issues. This section identifies these scenarios as well as issues and describes the Army's current practice in the absence of definitive EPA guidance. Additional discussions of alternative OB/OD closure strategies (e.g., performance vs. risk-based clean closure standards, etc.) are included in Appendix J.1. (Minor, et al., December 1995).

2.1 CLOSURE SCENARIOS

RCRA closure regulations prior to October 1998 basically presented only two closure options for Subpart X units: clean closure (i.e., removal of the OB/OD residues including risk-based closure), or closure as a landfill (i.e., capping the OB/OD residues that are left in place). EPA and the state regulatory agencies would ideally prefer clean closure, but they recognize that this may not be possible for all OB/OD units. For some OB and OD units, neither of the two options is satisfactory. For example, at OB and OD units where groundwater contains unacceptable levels of OB/OD residue constituents, clean closure is impossible. For such a situation closure as a landfill does not make sense either if the soil meets clean closure standards. Moreover, capping the soil in this case could actually impede groundwater remediation efforts. In such situations, the closure of OB and OD units should be performed in a manner that meets general closure performance standards as well as Subpart X environmental performance standards. In addition, the October 1998 closure/post-closure amendments promulgated by EPA provided greater flexibility to address closure with waste in place including scenarios in addition to closure as a landfill (USEPA, October 1998b).

The following is a more realistic list of typical OB/OD closure scenarios:

- Clean closure
  + Cleanup standards based on background/nondetection
  + Risk-based
- Closure with waste in place
  + Landfill closure
  + Partial closure
  + Delay of closure
  + Long-term remediation

These scenarios are discussed in this section and in Sect. 2.2. A summary of typical closure scenarios as a function of installation activity groups is presented in Sect. 2.1.3. Risk-based clean closure generally provides the greatest flexibility for the final closure of OB/OD units. However, the delay of closure approach may be beneficial for many inactive OB/OD units located within active military ranges.

In addition to RCRA-regulated OB/OD treatment operations, other earlier hazardous waste activities may have contributed to soil and groundwater quality conditions at a unit. Especially for sites operated prior to 1980, historical operations may be a major cause of these conditions and may complicate closure investigations and remediation. (However, only OB/OD units that received/treated hazardous waste after November 19, 1980 are subject to RCRA closure). Historical operations may have included disposal activities and/or the treatment of wastes other than energetics. The need for site investigation data to support closure decisionmaking is addressed in Sect. 2.2.2. Groundwater closure requirements would only apply if the unit received waste after July 26, 1982. Therefore, this guidance would not apply to these historical units; however, they may be subject to RCRA corrective action.

A hybrid closure approach (i.e., clean closure for certain portions of the unit and closure with waste in place for the remainder) may be considered on a case by case basis (see 52 Federal Register 8712, March 19, 1987).

2.1.1 Clean Closure

"The premise of clean closure is that all hazardous wastes have been removed from a given RCRA regulated unit and any releases at or from the unit have been remediated so that further regulatory control under RCRA Subtitle C is not necessary to protect human health and the environment." (USEPA, March 1998). Thus, clean closure does not involve the need for post-closure care to protect human health and the environment. EPA has issued guidance on risk-based clean closure (USEPA, March 1998). This guidance confirms that RCRA regulated units may be clean closed to protective, risk-based media cleanup levels. Prior to this risk-based closure policy the achievement of clean closure required the cleanup to background or nondetection standards. The application of risk-based and alternative clean closure criteria are discussed in Sect. 2.2.1. In addition, the October 1998 RCRA Closure/Post-Closure amendments promulgated by EPA facilitate use of the RCRA corrective action process to achieve closure (including clean closure) provided that certain prerequisite conditions are met as discussed in Sect. 4.1 (USEPA, October 1998b).

2.1.1.1 Clean Closure Overview

Clean closure may not be feasible for many OB/OD units (especially if background or nondetection cleanup standards are required). In order to achieve clean closure, all hazardous waste constituents must be removed as necessary to protect human health and the environment as well as to preclude the need for post-closure maintenance. The issue of "how clean is clean" is discussed in Sects. 2.2.1 and 2.3.3. However, the EPA policy on risk-based clean closure (March 1998) has helped to address this issue. Groundwater concentrations that exceed health criteria would eliminate the possibility of clean closure.

Unexploded ordnance (UXO) at closing OB/OD units is considered to be hazardous waste. The presence of large amounts of UXO would also increase the difficulty of achieving clean closure. At depths greater than 4 ft, UXO would be difficult to detect and remediate. A discussion of the UXO detection and remediation issue is presented in Sect. 2.2.3.

2.1.1.2 Risk-Based Clean Closure

EPA has issued a March 16, 1998 memorandum that confirmed and clarified guidance on risk-based clean closure for RCRA units (USEPA, March 1998). A copy of this memorandum is provided in Appendix J.4.

Risk-based clean closure should be seriously evaluated for OB/OD units on a site-specific basis. This closure option allows hazardous constituents and degradation products to remain in place at concentrations that do not endanger human health and the environment. Thus, OB/OD residues do not need to be removed or remediated to background levels to achieve risk-based clean closure. However, all hazardous waste must still be removed.

The risk-based clean closure guidance clarifies the amount of hazardous constituents that may be left in place and still meet clean closure standards. Specifically, constituent-specific human health and ecological impact criteria should be applied along with site-specific exposure factors and environmental setting data to characterize risks. EPA's position is that the risk assessment procedures and guidance available for RCRA corrective action and CERCLA cleanup programs are also appropriate to define the amount of hazardous constituents that may remain in environmental media after clean closure. (This also implies that site-specific, risk-based media cleanup levels developed under RCRA corrective action and CERCLA cleanup programs are also appropriate levels for RCRA closure).

EPA has generally considered an acceptable total residual cancer risk for humans from any medium to an individual exposed over a lifetime to be within a range from 10^{-6} to 10^{-4}. The cumulative cancer risk should not exceed 10^{-4} (with a preference for cleanup standards at the more protective and of the risk range). For noncarcinogens, EPA considers protective cleanup standards to be exposure concentrations that do not exceed constituent-specific health criteria (and the cumulative hazard index for chemicals that have a common toxicological endpoint should not exceed one). However, individual states may have their own health criteria and closure standards policy that would take precedence (assuming the State has RCRA closure authority).

Nonresidential (e.g., industrial) exposure assumptions have also been addressed in the EPA risk-based clean closure guidance. These non-residential exposure assumptions and health criteria are acceptable if risk information and associated land use controls demonstrate that human health and the environment will not be endangered (ecological risk assessment results need to be evaluated separate from the human health risk assessment).

The risk-based clean closure guidance cautions that reliance on physical barriers (e.g., fences) is not considered sufficient to ensure protection of human health and the environment. In addition, the guidance emphasizes that closure must protect both human health and the environment. Thus, ecological concerns may sometimes require more aggressive removal/ remediation efforts than might be necessary to protect human health.

Risk-based closure standards must also be based on the potential for cross-media migration of hazardous constituents (e.g., migration of constituents from soil to groundwater). EPA guidance clarifies the acceptability of the application of fate and transport models to evaluate cross-media migrations potential for hazardous constituents. Specifically, modeling can be used to evaluate the potential of hazardous constituents in soil to migrate to the air, surface water and groundwater in excess of human health and ecological impact criteria. Other fate and transport modeling applications (e.g., to evaluate impacts of leaving hazardous waste in place) are not appropriate for risk-based closures.

2.1.2 Closure With Waste in Place

Pursuant to RCRA, if clean closure is not achievable, the OB/OD unit must be closed with waste in place. "Waste in place" means that waste constituents and/or residues occur at concentrations greater than risk-based or alternative clean closure criteria (as discussed in Sect.

2.2.1) cannot be met. Closure with waste in place involves the need for post-closure care to protect human health and the environment. Therefore, the term "closure with waste in place" has been used in the guidance to refer to the following closure scenarios:

- Landfill closure
- Partial closure
- Delay of closure
- Long-term remediation

These scenarios are discussed in Sects. 2.1.2.1 through 2.1.2.4, respectively. Post-closure maintenance and monitoring as well as land use restrictions may also be needed for closure with waste in place.

The October 1998 RCRA closure/post-closure amendments promulgated by EPA provide the flexibility to use an alternative improvement processes (e.g., corrective action, etc.) to the standard RCRA closure process specified in Subpart G of 40 CFR 264 and 265 (USEPA, October 1998b).

2.1.2.1 Landfill Closure

Closure as a landfill involves the construction of a cap to mitigate the potential for migration of hazardous waste constituents from soils that contain OB/OD residues left in place. In addition, post-closure maintenance and groundwater monitoring are required by RCRA. Landfill cap specifications (i.e., the type of cap) should be based on site-specific potential contamination/exposure factors. Landfill cap requirements would need to be discussed with the lead regulatory agency on a case-by-case basis.

Long-term (typically 30 years) post-closure maintenance and groundwater monitoring are required by RCRA for closure as a landfill.

2.1.2.2 Partial Closure

Partial closure is a RCRA term that refers to the closure of some but not all hazardous waste management units at a facility. Regulatory agencies may require that inactive units in active OB/OD areas (e.g., closure of an OB trench or burn area collocated with an active OD unit) go through a formal partial closure process. For these cases, removal of any obvious debris and/or burn pans is reasonable. However, soil removal/remediation or installation of a landfill cap for the OB area would be neither useful nor cost-effective if the OD area continues to be active. A combination of soil and groundwater sampling data and a hazardous constituents migration (risk) assessment may be useful in demonstrating that partial closure can be deferred until final closure without endangering human health or the environment.

2.1.2.3 Delay of Closure

Delay of closure (frequently referred to as an administrative closure) is considered to be a temporary deferral of closure activities (i.e., without removal/remediation or the construction of a landfill cap). In some cases it may involve minimal removal/remediation (e.g., the cleanup of hot spots). This approach is warranted when current and future military activities preclude an effective RCRA closure and public access is restricted.

Precedence for administrative closure is being established (i.e., the Makua Military Reservation located in EPA Region 9 and Fort Dix, NJ located in EPA Region 2) for these situations. Delay of closure can involve the deferral of cleanup and corrective action activities at OB/OD units on active ranges until the range is closed. At that time, the OB/OD unit closure should be consistent with the cleanup requirements to be established under the Military Range Rule.

The following requirements may be anticipated for implementation of delay of closure:

- Conduct of a pre-closure site investigation and risk assessment to demonstrate that OB/OD residues will not endanger human health or the environment.
- Implementation of long-term security measures to control unit access.
- Long-term detection monitoring to demonstrate that hazardous waste constituents are not migrating off the unit.
- Limited land use.

The acceptability of the delay of closure concept to regulators will typically be limited to OB/OD units located within active military impact ranges. Under these circumstances, closure is complicated by the need to close the RCRA treatment unit while maintaining the active impact range. In many cases, the cleanup of UXO, debris, and soil will not be practicable because continuing range activities could adversely affect cleaned units. The exposure risks for delay of closure are different than for final closure (e.g., the public would not have access during delay of closure). The exposure risks for delay of closure are different than for final closure (e.g., the public would not have access during delay of closure).

2.1.2.4 Long-Term Remediation

Long-term soil and/or groundwater remediation may be appropriate to achieve risk-based or alternative clean closure criteria (as discussed in Sect. 2.2.1) for some OB/OD units. During the long-term remediation period, however, the OB/OD unit is still considered to have "waste in place" (i.e., OB/OD waste constituents and/or residues at concentrations greater than risk-based or alternative clean closure criteria, as discussed in Sect. 2.2.1). Long-term remediation for RCRA closure is considered as closure with waste in place and is typically addressed via a post-closure permit or alternative enforceable document. Alternative long-term remediation methods for soil and groundwater are discussed in Sects. 9.3.4.2 and 9.3.5, respectively.

2.1.3 OB/OD Units Within Active Ranges

OB/OD units at military training or testing operations may be located within designated impact ranges. Under these circumstances, closure is complicated by the need to close the RCRA treatment unit while maintaining the active impact range. (Military training and testing operations are RCRA-exempt.) Previous site investigation and UXO survey data frequently are not available to support the RCRA closure of the OB/OD unit.

The pervasive presence within the OB/OD unit of UXO from past military training and testing activities further complicates the successful completion of a RCRA closure. Furthermore, the potential for future impacts from munitions and ordnance use associated with military testing and training would negate the benefits of clean closing or capping the RCRA-regulated OB/OD unit prior to range closure. Based on the Munition Rule, UXO on active/inactive ranges would not be considered a waste munition. Therefore, OB/OD units located within active ranges may be candidates for delay of closure as discussed in Sect. 2.1.2.4. The objective of this approach is to defer cleanup of the OB/OD unit until range closure. A precedent for delay of closure is being established (i.e., the Makua Military Reservation, HI, located in EPA Region 9 and Fort Dix, NJ located in EPA Region 2). EPA Region 9 is considering the use of BRAC to coordinate closure of the OB/OD unit at Makua Military Reservation as well as range closure. However, it can be anticipated that there will be a wide range of approaches, especially by states, regarding the closure of OB/OD units within ranges.

2.2 CLOSURE ISSUES

The development of OB/OD closure strategies, the preparation of closure plans, and the implementation of closure requirements involve many significant issues, including the following:

- How clean is clean?
- Baseline/pre-closure site investigations
- UXO detection and clearance
- Natural attenuation

A discussion of each of these issues is presented in Sects. 2.2.1 through 2.2.4, respectively. Additional closure issues which are still unresolved are discussed in Sect. 2.3.

2.2.1 How Clean is Clean?

Cleanup criteria need to be established for clean closure. The issue of how clean is clean can be quite controversial. Typically the owner/operator must identify and justify the process for determining clean closure performance standards as part of the closure plan.

Alternative screening criteria for defining clean closure include the following:

- Background levels

- Quantitative analytical detection limits (i.e., the limit below which quantitative values are considered unreliable)

- Nondetection levels (i.e., below the ability of the analytical equipment to qualitatively determine the presence of the hazardous waste constituent of concern)

- Best demonstrated available remediation technology

- Regulatory precedent (e.g., Records of Decision at Superfund sites and decisions by regulatory agencies for similar situations)

- Existing standards or guidelines

- Combinations of the above.

The pros and cons as well as information resources for these alternative methods are summarized in Sect. 8.1.

The appropriate regulatory agency should be contacted to identify and discuss applicable clean closure guidance and associated criteria. Typically, the approach to demonstrate clean closure involves one or more of the following steps:

- Comparison to background levels
- Comparison to agency-specific screening criteria
- Risk-based cleanup criteria

An alternative approach is to consider an administrative or deferred (until range closure) closure when OB/OD units are located in active impact ranges, as discussed in Sect. 2.1.2.4.

States and various EPA Regions may have their own screening criteria which generally provide a conservative approach to defining cleanup criteria. Screening criteria developed by EPA Regions 3 and 9 have had widespread use in other EPA Regions and many states. However, screening criteria exceedances are only a first step toward a potential cleanup. Screening criteria exceedances suggest that a conventional risk assessment should be conducted. If the risk assessment indicates inapplicable risk, then a cleanup may be in order.

The most prevalent approach for defining clean closure standards has been based on site-specific, risk-based cleanup criteria. EPA has issued risk-based clean closure guidance (USEPA, March 1998). This guidance confirms that, under current regulations, RCRA- regulated units may be clean closed to protective, risk-based cleanup levels. Furthermore, the guidance encourages the use of risk-based cleanup criteria. All hazardous waste must still be removed but hazardous constituents can remain as long as they are protective of both human health and the environment. The guidance facilitates the use of either residential or nonresidential exposure assumptions based on expected land use. In addition, EPA guidance endorses the use of fate and transport models to determine site-specific, risk-based cleanup criteria. The technical approach for the determination of site-specific, risk-based cleanup criteria is explained in Sect. 8.

Additional discussions of alternative OB/OD closure strategies (e.g., performance vs. risk-based closure standards, etc.) are included in Appendix J.1 (Minor et al., December, 1995).

2.2.2 Baseline/Pre-Closure Site Investigations

Baseline site investigation data to characterize current hazardous waste constituent concentrations in soil and groundwater are needed for inclusion in OB/OD permit applications based on EPA guidance. These data provide critical input for the conduct of risk assessments and the determination of site-specific environmental performance standards. Many installations presently do not have current, adequate, or any OB/OD site investigation data. Therefore, site investigations should be conducted now to support either permitting or closure of RCRA OB/OD units which have interim status.

A pre-closure site investigation of the unit is needed to define the nature, magnitude, and spatial extent of residues from OB/OD operations. Baseline site investigation data, if recent, may also serve as pre-closure site investigation data. Verification sampling will also be needed after completion of clean closure. Post-closure groundwater monitoring will be required for closure as a landfill.

The baseline/pre-closure site investigations are intended to characterize hazardous waste constituents in soil and groundwater attributed to OB/OD operations as well as other waste management activities. In addition to the RCRA-regulated OB/OD treatment operations, other earlier hazardous waste activities may have contributed to the hazardous waste constituent concentrations at a unit. Especially for sites operated prior to 1980, historical operations may be a major cause of hazardous waste constituents in the soil/groundwater and may complicate closure investigations and remediation. (Only OB/OD units that received/treated hazardous waste after November 19, 1980 are subject to RCRA closure and groundwater monitoring closure requirements only apply if the unit received waste after July 26, 1982). Historical operations may have included disposal activities and/or the treatment of wastes other than energetics. There may be a need to conduct a broad-scope evaluation of site conditions (i.e., similar to a RCRA Facility Investigation [RFI]) if institutional knowledge of the activities which preceded RCRA notification has gone undocumented. Conservatism may be relaxed if restricted access to the area is contemplated as part of closure.

The design of the site investigation for closure should consider the results of any previous studies (e.g., RFIs, remedial investigations/feasibility studies [RI/FSs], baseline sampling, routine monitoring, etc.). In addition, coordination of Base Realignment and Closure (BRAC)/Installation Restoration Program (IRP), RCRA, and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements/actions at the time of closure should be a major goal. The potential for site investigation cost avoidance from this coordination effort can be significant if investigation data can serve multiple needs.

Baseline/pre-closure site investigations involve soil sampling and, as applicable, may also involve sediment, surface water, and/or groundwater sampling. The need for pre-closure groundwater sampling/monitoring will be driven by lead regulatory requirements and policy, as well as local land and groundwater use. Thus, there may be a significant variation in groundwater monitoring requirements between installations. The presence of UXO (i.e., UXO safety hazards) and, in certain cases, climate (e.g., high water levels in locations such as Florida, and some cold climates) may limit the installation of groundwater wells. The application of direct-push techniques should be considered on a case-by-case basis as a cost-effective alternative to the installation of groundwater monitoring wells. However, installation-specific groundwater monitoring requirements should be based on regulatory negotiations. In addition, if wells are required, their purpose may or may not be long-term monitoring depending on the type of closure, analytical results, and regulatory comments.

A detailed discussion of the technical approach for the conduct of OB/OD pre-closure site investigations is provided in Sect. 6. Guidance on the conduct of site characterization screening assessments (i.e., baseline studies that are less comprehensive than a site investigation) to support operating permit versus unit closure decision making is provided in the U.S. Army Open Burn/Open Detonation Unit Management Guide (U.S. Army, January 1999).

2.2.3 UXO Issues at Detonation Craters

The potential for UXO exists at OD units. There is a limited potential for UXO at some OB units that treated munitions components, such as fuzes, and munition items. EPA's Munitions Rule clearly indicates that military munitions sent to OB/OD units for treatment should be considered hazardous waste. The presence of UXO at closure of a RCRA OD unit presents an immediate explosives safety hazard for the conduct of site investigations and remedial actions as well as for future land use. UXO and/or munition fragments can be created through the subsurface OD treatment process. At some sites, frost-heave or erosion may allow UXO to surface over time. UXO may also present a potential chronic human health and environmental risk concern. Constituents may be released from UXO that have been damaged upon detonation or may deteriorate over time. Thus, it may be necessary to conduct a UXO survey and subsequent UXO response at the detonation craters based on site-specific conditions and closure requirements. This support should be provided by Explosive Ordnance Disposal (EOD) or UXO specialists. (See Appendix H for UXO management/safety guidance and Appendix I for UXO detection methods.)

2.2.4 Natural Attenuation

The concept of natural attenuation may initially appear to be an alternative approach to remediation to achieve closure of an OB/OD unit. The "natural attenuation processes" that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of hazardous waste constituents in soil or groundwater. These in-situ processes include biodegradation, dispersion, dilution, adsorption, volatilization, and chemical or biological stabilization or destruction of contaminants. Natural attenuation processes are occurring at all sites, but to varying degrees of effectiveness depending on the types of hazardous waste constituents present and the physical, chemical, and biological characteristics of the soil and groundwater.

EPA has issued a policy memorandum entitled "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites" (USEPA, April 1999). A copy of this guidance is provided in Appendix J.7. This document reaffirms EPA's position that natural attenuation is an alternative to remediation in some cases, providing the following criteria are met:

- Site-specific remediation objectives will be achieved within a reasonable time frame.
- A site-specific site characterization and risk assessment indicate that human health and the environment will not be endangered.
- Additional source controls will be implemented as necessary.
- A site-specific performance test has been conducted which demonstrates the effectiveness of natural attenuation.

- Performance monitoring is required as long as constituent levels in soil and groundwater remain above required cleanup levels on any portion of the unit.

The EPA does not generally consider monitored natural attenuation to be a "no action" remedy. Furthermore, its applicability to OB/OD units may be significantly limited since metals (which are less amenable to short-term natural attenuation) are expected to be major constituents of concern at many sites.

3. OVERVIEW OF OPEN BURNING AND OPEN DETONATION TREATMENT OF ENERGETIC WASTES

Open burning and OD are used by the U.S. Army and other Military Services for the thermal treatment of energetic wastes. These wastes typically consist of bulk propellants, explosives, and conventional munitions, all of which are classified as unserviceable, unstable, or unusable (see Fig. 3-1).

Certain items are prohibited from routine treatment by OB/OD, such as military chemical warfare agents or related compounds, or materials contaminated with these agents. A second group of compounds or mixtures that should not be treated on a routine basis except under emergency conditions include (U.S. Army, October 1996):

- Hexachloroethane
- Colored smokes
- White phosphorus
- Red phosphorus
- Riot-control munitions

Finally, OB/OD should not be conducted if any waste is not reactive.

3.1 OPEN BURNING

Open burning has been used to treat energetic wastes by self-sustained combustion, which is ignited by an external source (such as a flame, heat, or detonation wave that does not result in an explosion) (USEPA, September 1993a). Typical energetic wastes treated by OB include bulk propellants and energetic material items which are not reliably detonable and/or can be burned without causing an explosion (see Fig. 3-2). Occasionally, OB has been used for the treatment of solvents that contain energetic constituents.

In the past, OB was frequently conducted on the ground surface or in burn trenches. Current best management practice for OB involves the use of burn pans to contain the energetic waste prior to treatment as well as the residue and ash from the burn. Based on field tests conducted by the U.S. Army, the OB ash/residue from the treatment of bulk propellants is approximately a factor of 10^{-3} of the original energetic waste mass (U.S. Army, January 1992).

Dunnage (such as wood) and supplemental fuels (such as fuel oil or kerosene) have been used to aid the burning in certain circumstances. For example, dunnage is used for the treatment of wet energetic wastes. Burn cages or burn pans have also been used for burns with dunnage.

An area of approximately 200 ft around the burn pan is generally kept clean of vegetation as a fire prevention measure pursuant to U.S. Army Materiel Command, Explosives Safety Manual, AMC-R 385-100 (U.S. Army, 1985). At some installations, herbicides may have been used to control vegetation.

Open burning and static firing have also been used for the demilitarization of rocket and missile motors. In some cases the treatment has involved OB directly on the ground or in trenches. Mounting stands have been used for the static firing of rocket and missile motors.

3.2 OPEN DETONATION

Open detonation has been used as the primary method for the treatment of waste explosives and certain munitions (see Fig. 3-3). Open detonation directly on the ground surface is a frequently used treatment method. Typically, a donor charge is used to increase the effectiveness of treatment. Frequently the detonations are conducted in pits to minimize fragmentation dispersal and noise impacts. Both open pits and buried charges (i.e., subsurface detonations) have been used for OD treatment (USEPA, September 1993a).

3.3 POTENTIAL CONTAMINATION FOR RESIDUES FROM OB/OD OPERATIONS

The soil is the primary medium of concern during closure of OB/OD units (see Fig. 3-4). However, OB/OD constituents in the soil, if present, generally occurs in the immediate vicinity of the treatment area and may be attributed to spillage of propellant and OB ash and residue as well as direct contact with the soil (e.g., ejecta fallout) during the treatment process.

OB/OD residues in the soil can become a source for OB/OD constituents in the groundwater (via infiltration). In addition, the residues in the soil can migrate from the groundwater to surface water. Overland runoff from the OB/OD unit can also affect surface water quality as well as result in sediments that contain OB/OD constituents.

The U.S. Army has been conducting site investigations and emission tests to characterize potential environmental effects attributed to OB/OD releases. During the period of 1981-1985, the U.S. Army Environmental Hygiene Agency (USAEHA) collected and analyzed soil and groundwater samples at numerous OB/OD sites. These results have been summarized to obtain an overview of the potential for OB/OD residues (U.S. Army, October 1985; U.S. Army, February 1986).

The Army has also been conducting OB/OD emissions tests using a test chamber (BangBox) and some limited field studies (which have included soil deposition samples). Initial tests were sponsored by the U.S. Army Armament, Munitions and Chemical Command (AMCCOM) and the U.S. Air Force Air Combat Command (USAFACC) (U.S. Army, January 1992; U.S. Army, January 1994). Additional tests have been conducted at DPG based on sponsorship by SERDP and the Military Services. These studies have provided insight to identifying potential constituents of concern (COC) as well as characterizing the potential for residues attributed to OB/OD operations.

3.3.1 OB/OD Residues in Soil

A summary of the potential area and depth of soil with constituents from OB/OD operations is presented in Fig. 3-5 based on various Army studies (i.e., the USAEHA and U.S. Army Armament, Munitions, and Chemical Command (AMCCOM) studies referenced above).

The USAEHA site investigation study included soil sampling at a wide range of OB and OD sites throughout the continental United States (U.S. Army, February 1986). Screening surface soil samples (to a depth of 18 in.) were collected by the Army at 36 installations with OB/OD areas. A total of 1,541 samples were collected and analyzed for 14 chemical parameters (metals and energetics), resulting in a total of 21,574 separate chemical analyses. Approximately 99% of these 1981-1985 samples were below RCRA Extraction Procedure Toxicity (EP Tox) limits for the metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver). (The current RCRA toxicity characteristic leaching procedures were not applicable when the samples were analyzed.) Similarly, about 99% of the results for energetics were below 1,000 μg/g. Tests conducted by the Army have indicated that soils containing explosives in concentrations of 100,000-120,000 μg/g (10-12%) or less were not reactive.

3.3.1.1 OB Residues in Soil

Additional soil samples were collected at OB areas for 12 of the Army installations included in the screening phase study (U.S. Army, February 1986). Historically, burn pans were not used at many of these sites. Current practice is to use burn pans to minimize the potential for OB residues to come in contact with soils. The typical strategy for determining sampling depths was to collect an initial sample at a depth of 1.5 to 2 ft, with subsequent samples collected every 5 ft or change of strata. Drilling was generally terminated upon interception of groundwater or refusal. A small number of samples were also collected from the top 18 in. of soil.

Significant soil concentrations of OB residue constituents were detected at the OB areas of 9 of the 12 installations included in the followup study. Soils at many of these sites contained concentrations of metals that exceeded the applicable EP Tox limits. Therefore, these soils were considered to be hazardous waste. However, this condition was generally limited to the top 18 in. of soil. Vertical and lateral subsurface migration was not a primary concern, based on the sampling results. However, local conditions were conducive to runoff-related migration of OB constituents at 5 of the 12 installations evaluated. In some locations, the potential existed for significant concentrations of OB residue constituents in downgradient soils and/or surface waters due to overland migration. Since only EP Tox results were presented in the report cited, a comparison of sampling results to health criteria is not available. The current practice of using burn pans is expected to reduce the potential for OB residues in the soil compared with the results based on historical practices at the 12 installations evaluated.

Open burn field tests conducted at DPG have indicated that residues were generally limited to within 10-20 m of the burn pans. Potential OB residues constituents in the soil may occur in the immediate vicinity of the pans because of spillage (loading the burn pans with propellant and/or unloading the post-burn residue and ash). Ejecta and "pop outs" from the burns are another potential source of contamination (U.S. Army, January 1992).

3.3.1.2 OD Residues in Soil

Surface residues at OD sites was less than that detected at OB sites based on the USAEHA soil sampling study (U.S. Army, February 1986). However, OD areas are considered to have a greater potential for subsurface residues in the form of small but concentrated "hot spots." Other site-specific soil sampling data indicate that subsurface residues at OD units can be related to detonation crater depths. The crater depth can be estimated as follows (DNA, October 1981):

$$D_a = (0.5)\,(V_{ac})^{1/3} \qquad \text{Eq. 3-1}$$

where

D_a = apparent crater depth (m)

V_{ac} = apparent crater volume (ft^3)

The relationship between crater depth and OD residue concentration is useful. However, the craters may be reshaped after each detonation event. In some cases, over the course of the operation craters have actually been leveled or moved. Therefore, soils may be mixed, leaving no discernible residue pattern, Also, live ordnance and other ordnance items may be buried in crater soils.

The expected apparent crater volume has been based on the following equations (DNA, October 1981):

$$V_{ac} = V_{cd} \ x \ W_{gc} \ \exp[-5.2 H_b \ (V_{ce} \ W_{gc})^{-0.33}] \qquad \text{Eq. 3-2}$$

where

V_{ce} = cratering efficiency for a zero height of burst based on Table 3-1 (ft^3/ton)

W_{gc} = trinitrotoluene (TNT)-equivalent net explosive weight relative to ground cratering (tons)

H_b = height of the burst in feet; negative if below ground with soil cover (not applicable to more than a few charge radii below the surface)

and

$$W_{gc} = TF \ x \ W \qquad \text{Eq. 3-3}$$

where

TF = TNT-equivalent weight factor relative to ground-cratering efficiency which is related to total energy content and not to detonation velocity

W = net explosive weight detonation charge (tons)

The TNT-equivalent weight factor relative to ground-cratering efficiency generally ranges from 0.68 (for dynamite) to 1.34 (for C-4 explosives typically used as a donor charge) (DNA, October 1981).

Table 3-1. Summary of cratering efficiency values, V_{ce}

Medium	V_{ce} (ft^3/ton) Range	Best estimate
Wet geology (including soils and clay shales)	2,000 to 8,000	4,000[a]
Dry soil	600 to 1,800	1,000[b]
Dry soft rock	500 to 1,200	800
Dry hard rock	300 to 700	500

[a]Wet clay = 10,000
Wet sand = 6,000
Wet coral sand = 4,000

[b]Dry clay = 1,500
Dry sand = 1,500
Dry alluvium = 1,100
Playa = 800

Source: DNA, October 1981.

Open detonation field tests conducted at DPG have indicated that 97-98% of the measured OD residue constituents in soil occurred in the immediate vicinity of the crater. The remainder (2-3%) was within a 200-m radius for a 2,000 lb NEW detonation (U.S. Army, January 1994).

3.3.2 OB/OD Residue Constituents in Groundwater

The potential for OB/OD residue constituents in groundwater from OB/OD surface soils is illustrated in Fig. 3-6 based on Army studies.

The USAEHA study to characterize OB/OD also included the collection and evaluation of groundwater samples (U.S. Army, October 1985). Groundwater quality was investigated at 19 OB/OD Army facilities by obtaining samples from a total of 109 monitoring wells. Analysis was accomplished for heavy metals, explosive compounds, and, at half the installations, purgeable and extractable organic substances.

Using a conservative method of interpretation, 9 of the 19 facilities showed some type of groundwater quality effects attributable to OB/OD operations. Nonbackground levels of metals exceeded criteria at only two sites, and nonbackground levels of volatile organics exceeded criteria at two other sites. Explosives parameters exceeded criteria at eight locations.

3.3.3 Constituents of Potential Concern

Potential emissions from OB/OD units include products of combustion as well as products of incomplete combustion (see Fig. 3-7). Together these emissions can be referred to as combustion by-products. Energetic compounds are composed principally of carbon, hydrogen, nitrogen, and oxygen. The primary emissions are products of combustion and typically include the following (U.S. Army, May 1995):

- Carbon monoxide
- Carbon dioxide
- Nitrogen and nitrogen oxides
- Water
- Sulfur dioxide
- Methane

Secondary emissions include products of incomplete combustion (which can include energetic materials, organics, and metals).

Principal energetics of concern (considering prevalence and the availability of health criteria) include the following:

- RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)
- HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)
- TNT (2,4,6-Trinitrotoluene)
- DNT (2,4- and 2,6-Dinitrotoluene)
- DNB (1,3-Dinitrobenzene)
- HCE (Hexachloroethane)
- Tetryl (Methyl-2,4,6-trinitrophenylnitramine)
- TNB (1,3,5 Tinitrobenzene)

The following additional target analytes for energetics should be considered for OB/OD closures on a case-by-case basis, considering knowledge of site waste treatment/disposal practices and regulatory negotiations:

- TNG (Trinitroglycerol [nitroglycerin])
- PETN (Pentaerythritol tetranitrate)
- Nitroglycerin (NG)
- NQ (Nitroguanidine)

- WP (White phosphorus)
- EGDN (Ethylene glycol dinitrate)
- PGDN (Propylene glycol dinitrate)
- Picric acid
- Picramic acid

The energetics listed above are not considered standard target analytes since they generally require special analytical methods and additional analytical costs.

Metals of potential concern include the following (which represent metals that typically are part of the composition of munitions, propellants, and explosives and associated casings) (U.S. Army, May 1995).

- Aluminum
- Antimony
- Arsenic
- Barium
- Boron
- Calcium
- Chromium
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Nickel
- Potassium
- Silver
- Sodium
- Strontium
- Tin
- Titanium
- Zinc

A list of other potential OB and OD combustion by-products is presented in Table 3-2. These contaminants have been identified based on OB/OD emissions tests which included the participation of EPA in a quality assurance oversight role (U.S. Army, January 1992; U.S. Army, January 1994; U.S. Army, May 1995). These studies initially evaluated a comprehensive range of potential constituents which was narrowed down based on nondetect results. This list should be periodically reevaluated as additional OB/OD emission data from the BangBox tests at DPG become available.

The BangBox data indicated that volatile organic compounds (VOCs) are not a significant concern from OB/OD emissions (U.S. Army, January 1992). However, there is the potential for emission of chlorinated compounds associated with the treatment of some propellants.

Herbicides may also be of concern at some sites if used for clearing vegetation as a fire-prevention measure.

Table 3-2. Summary of potential OB/OD combustion by-products — other combustion by-products

Other combustion by-products	OB	OD
1-Nitropyrene	√	√
1,3-Butadiene		√
1,3,5-Trinitrobenzene	√	√
1.6-Dinitropyrene	√	
2-Methylnaphthalene		√
2-Methylphenol		√
2-Naphthylamine	√	
2-Nitrodiphenylamine	√	√
2-Nitronaphthalene	√	√
2,2[1]-Methylene bis (4-methyl-6-t-butyl phenol)	√	
4-Nitrophenol		√
5-ethyl-1,3-diglycidyl-5-methylhydentoin diepoxide	√	
Acenaphthylene		√
Acetophenone		√
alpha, alpha-Dimethylphenethylamine		√
Ammonia	√	√
Anthracene		√
Aromatics (VOs, including benzene)		√
Benzene	√	√
Benz(a)pyrene	√	√
Benz(b)fluoranthene		√
Benzyl alcohol		√
Benzo(k)fluoranthene		√
Benzo(a)anthracene	√	√
Benzo(c)acridine	√	
Butyl benzyl phthalate		√
Chrysene		√
Dibenzofurans	√	√
Dibenz(a,h)anthracene	√	√
Di-n-butyl phthalate		√
Diethyl phthalate		√
Diethylenetriamine	√	
Dimethyl phthalate		√

Table 3-2. (Continued)

Other combustion by-products	OB	OD
Di-n-octyl phthalate		√
Di-n-propyladipate	√	
Dioctylsebacate	√	
Diphenylamine	√	√
Di(2-ethylhexyl)phthalate		√
Ethyl benzene		√
Fluoranthene		√
Fluorene		√
Hexane		√
Hydrogen cyanide	√	√
Isophoronedi-isocyanate	√	
Methane		√
Naphthalene	√	√
Nitric oxide	√	√
N-Nitrosodiethylamine		√
N-Nitrosodiphenylamine	√	√
Olefins (VOs)		√
o-Nitrophenol	√	
Paraffins (VOs)		√
Phenanthrene		√
Phenol	√	√
Phenyl diisodecylphosphite	√	
Pyrene	√	√
Resorcinol	√	
Salicylic acid	√	
Styrene		√
TNMHC (Total nonmethane hydrocarbons)	√	√
TO-12 (Total Organics C2-C15)		√
Toluene		√
Triacetin	√	
Xylenes (Isomers and mixtures)		√

√ Detected during available OB/OD emission tests.

Sources: U.S. Army, January 1992; U.S. Army, January 1994; U.S. Army, May 1995.

The OB/OD site investigation data from the USAEHA study suggest the following conclusions (U.S. Army, October 1985; U.S. Army, February 1986):

- Barium and lead are primary metals of concern based on prevalence in the soil and groundwater and exceedances of TEP limits. However, there is the potential for other metals such as cadmium, chromium, arsenic, and mercury to represent a high risk at some sites.

- The explosives most frequently detected in soil at OB sites in significant concentrations were, in order of decreasing frequency of detection, TNT, 2,4-DNT, RDX, HMX, and 2, 6-DNT.

- The most commonly found explosives in groundwater were TNT, RDX, and 2,4-DNT, followed by 2,6-DNT and HMX.

- Based primarily on apparent leaching potential, the explosives RDX, TNT, and 2,4-DNT should be of greater concern at OB/OD sites than 2,6-DNT, HMX, and tetryl.

- Organic contamination should not be a problem at OB/OD units if:

  (1) Energetic wastes are not placed in unlined OB pits or OB trenches at or very near the water table.

  (2) Explosive wastes are not treated at or near the water table for OD.

  (3) Nonexplosive organic compounds are not disposed of at these OB/OD units.

At OB and OD sites, the most commonly found explosives in surficial materials, at both high and low concentrations, were TNT, RDX, and HMX, followed by 2,4-DNT and 2,6-DNT. The most commonly detected explosives in groundwater were TNT, RDX, and 2,4-DNT, followed by 2,6-DNT and HMX. Tetryl was never detected in groundwater. 2,6-DNT was found in groundwater only where 2,4-DNT also was detected. In addition, 2,6-DNT was found in groundwater at a concentration exceeding 2 μg/L at only one location, where it was also present in soil samples at high concentrations and in the waste buried in the trench which intercepted the water table. The HMX was confirmed in only two groundwater monitoring wells, whereas it was found in surficial material at 14 sites, half of them at high concentrations. However, RDX was confirmed in groundwater at every site but one. RDX also exceeded its health criterion at every site where it was detected in groundwater.

Although these data are empirical and do not represent controlled research findings, it appears that these explosives display different leaching potentials. The explosives of most concern, based on a combination of leachability, frequency of use, and assumed potential health risk, are RDX followed closely by TNT and 2,4-DNT. The explosives of least concern are 2,6-DNT, HMX, and tetryl. Where 2,6-DNT wastes were not deposited directly into the water, the highest confirmed concentration was only 2 μg/L. Apparently, HMX has a low health risk potential and a relatively low leaching potential. Tetryl has been infrequently used and is relatively unstable in water.

Only one facility showed "explosive-related" organic compounds. (For this case the waste was exposed directly to the groundwater.) Only one other installation displayed evidence of significant organic contamination emanating from the OB area, where substantial concentrations of trichloroethylene, carbon tetrachloride, and chloroform were found in most wells. The conclusion from these data is that if explosive wastes are not placed in pits or trenches at or very near the water table, and if VOCs are not disposed of at these facilities, organic contamination (other than the basic explosives themselves) should not be a problem at OB/OD sites.

3.3.4 OB/OD Residues

OB/OD debris (e.g., shrapnel from fragmentation and other waste munition components) can be generated during the OB/OD treatment of waste munitions. These OB/OD debris can be energetic-contaminated or have other hazardous characteristics and constituents (unexploded ordnance is discussed in Sec. 3.3.5). Visible inspections by EOD and UXO trained specialists can be used to evaluate the site-specific nature and extent of OB/OD debris. The management and disposition of OB/OD debris should address explosive safety, demilitarization (trade security), and environmental requirements as discussed in Sect. 9.2.2.4.

3.3.5 Unexploded Ordnance

The potential for unexploded ordnance exists at OD units and OB units which have been used to treat munitions. UXO is also a concern for all OB/OD units located within military impact ranges. When live ordnance items and/or debris have been buried by natural processes or operations, ordnance and ordnance-related items may continue to surface over time. Thus, it may be necessary to conduct a UXO survey and subsequent UXO clearance based on site-specific conditions and closure requirements.

UXO associated with OB/OD treatment operations is expected to occur on the ground surface and at depths commensurate with OD pits and craters. However, UXO can occur at greater depths at OB/OD sites located within military ranges associated with range operations. A discussion of UXO detection and clearance issues has been presented in Sect. 2.2.3.

3.3.6 Other Previous Hazardous Waste Activities

In addition to the RCRA-regulated OB/OD treatment operations described in this section, other earlier hazardous waste activities may have contributed to the quality of soils and groundwater at a unit. Especially for sites operated prior to 1980, historical operations may be a major cause of hazardous constituents in soils and groundwater and may complicate closure investigations and remediation. Only OB/OD units that received/treated hazardous waste after November 19, 1980 are subject to RCRA closure. Groundwater monitoring closure requirements only apply if the unit received waste after July 20, 1982. Therefore, this guidance would not apply to these historical units. However, they may be subject to RCRA corrective action.

Historical operations may have included disposal activities and/or the treatment of wastes other than energetics. There may be a need to conduct a broad-scope evaluation of site conditions (i.e., similar to a RFI) if institutional knowledge of the activities which preceded RCRA notification has gone undocumented. Conservatism may be relaxed if restricted access to the area is contemplated as part of closure.

4. SUMMARY OF RCRA REGULATIONS ASSOCIATED WITH OB AND OD CLOSURE

Regulations promulgated under RCRA govern the "cradle to grave" management of hazardous waste. These regulations prescribe requirements applicable to generators, storers, transporters, treaters, and disposers of hazardous waste. Among these regulations are requirements specific to facility closure.

Open burning and OD units are considered waste treatment units under RCRA. Consequently, all owners/operators of currently operating OB and OD units will have to close them in accordance with RCRA requirements. Owners/operators of many OB and OD units will have to comply with related requirements applicable to post-closure care, groundwater monitoring, and corrective action. Closure and related requirements are described in the following sections of this guidance (see Fig. 4-1):

- Overview of closure for OB and OD units
- Closure context for OB and OD units
- RCRA closure requirements
- Post-closure care
- Related regulatory requirements

This section does not describe regulations applicable to financial responsibility for closure and post-closure care because Federal facilities are exempt from these requirements.

4.1 OVERVIEW OF CLOSURE FOR OB AND OD UNITS

The goals of RCRA closure are to

- protect human health and the environment, and
- minimize the need for post-closure maintenance.

The RCRA closure process (pursuant to 40 CFR 264 Subpart G for permitted units and 40 CFR 265 Subpart G for interim status units) always involves the preparation of a closure plan, the performance of closure in accordance with regulatory requirements, and certification that closure was performed in accordance with the closure plan. At OB/OD units where wastes will remain in place (i.e., waste constituents and/or residues at concentrations that exceed risk-based or alternative clean closure criteria as discussed in Sect. 2.2.1) after closure also involves complying with requirements applicable to documenting the placement of waste on survey plats and deeds, the preparation of post-closure plans, post-closure permitting or (pursuant to the October 1998 closure/post-closure amendments) alternative enforcement mechanism, the performance of post-closure care, and certification of post-closure care.

Regulator experience with the closure of OB and OD units is limited. Because it is difficult to predict if OB and OD units will achieve "clean closure" (including risk-based clean closure) "contingent" closure and post-closure plans should be prepared for OB and OD units if clean closure is planned as part of the RCRA closure process pursuant to EPA guidance (USEPA, March 1997).

The October 1998 closure/post-closure amendments have facilitated greater regulatory flexibility to achieve RCRA closures as illustrated in Figs. 4-2 (for OB/OD units that intend to clean close) and 4-3 (for OB/OD units that intend to close with waste in place). The RCRA corrective action process can be used instead of the standard RCRA closure process (i.e., Subpart G of 40 CFR 264 and 265) provided that the following prerequisites are met:

- The closure unit must be situated among SWUMs and/or areas of concern (AOCs)
- Both the closure unit and SWMUs/AOCs are likely contributors to a release
- Corrective action process is deemed protective of human health and the environment
- Cleanup remedy will satisfy RCRA closure performance standards.

Units that never had interim status should be closed using the RCRA corrective action process.

In addition, nonpermitted units that intend to close with waste in place can utilize an alternative enforcement process and use alternative enforceable documents to address RCRA closure and post-closure requirements. However, the selection of the closure process (i.e., Subpart G, corrective action or alternative mechanism) is at the discretion of the lead regulatory agency. Therefore, options for alternative closure processes/documents should be discussed with the lead regulatory agency on a case-by-case basis. In addition, since the October 1998 closure/post-closure amendments are not more restrictive than Subpart G, states with RCRA program authorization of 40 CFR 264 and 265, are not required to adopt the amendments.

4.2 CLOSURE CONTEXT FOR OB AND OD UNITS

Facility closure requirements vary according to facility status (interim status or permitted), the type of unit, the state in which the facility is located, and guidance that addresses specific facility situations. This section discusses how the context of facility closure influences facility closure requirements. A summary of RCRA closure requirements for OB/OD units is presented in Appendix J.

4.2.1 Facility Status

Under RCRA, there are two categories of TSDFs, based on a facility's permit status.

- The first category is made up of "interim status" facilities that have not obtained a permit.
- The second category is made up of "permitted status" facilities that have obtained permits.

The lead regulatory agency should be contacted regarding site-specific closure requirements for nonpermitted facilities that do not have interim status.

Interim status facilities are regulated under 40 CFR 265; permitted facilities are regulated under 40 CFR 264. RCRA permitting requirements are located in 40 CFR 270. The permitting requirements specify that a closure plan for the units to be permitted must be submitted with RCRA Part B permit applications.

Interim status OB and OD units are thermal treatment units.

- Technical regulations specific to thermal treatment units are located in Subpart P to 40 CFR 265.
- Closure regulations applicable to interim status units are located in 40 CFR 265, Subpart G.

Permitted OB and OD units are miscellaneous units.

- Technical regulations specific to miscellaneous units are located in Subpart X to 40 CFR 264.
- Closure regulations applicable to permitted units are located in 40 CFR 264, Subpart G.

Fig. 4-4 illustrates the relationship of these regulations.

4.2.1.1 Qualifications for Interim Status

The original RCRA legislation allowed owners and operators of TSDFs in existence on November 19, 1980 (or brought under Subtitle C regulation due to a statutory or regulatory amendment) to continue to operate under interim status until their permit was issued or their request for a permit was denied as long as they:

- submitted notification of hazardous waste activity and described the location and general nature of the activity under Section 3010(a) of RCRA,
- submitted a RCRA Part A Permit Application six months after the publication of a regulation that rendered the facility subject to interim status standards, or 30 days after the facility first became subject to these standards,
- complied with all interim status standards, and
- submitted a RCRA Part B permit application within 6 months of a request for such application by a EPA Regional Administrator or the director of the state environmental agency administering the RCRA program (40 CFR 270.10).

The passage of the 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA altered these requirements by setting deadlines ("hammers") for facilities with interim status as of November 8, 1984, to submit RCRA Part B permit applications. The deadline for treatment and storage units (not including incinerators) was November 8, 1988. Failure to submit a RCRA Part B permit application by that date resulted in loss of interim status on November 8, 1992.

The U.S. Army submitted Part A and Part B permit applications for most of its OB and OD units in conformance with these deadlines. Currently, most Army OB and OD units still have interim status because EPA and the states have made few permit decisions.

Owners and operators of new facilities (including new OB and OD units) are not eligible for interim status. (New facilities are defined as facilities not in existence or under construction on November 19, 1980 or on the effective date of the statutory or regulatory requirements rendering them subject to RCRA permit regulations.) Owners and operators of new facilities are required to apply for a RCRA permit at least 180 days before construction of the facility is expected to begin. Consequently, closure plans for new facilities must be approved as part of the RCRA permitting process even before the facilities are constructed.

4.2.1.2 Permitting of Interim Status Units

When an interim status facility is permitted, the facility submits its closure plan to the appropriate regulatory agency as part of the RCRA Part B permit application. The regulator reviews and comments on the closure plan in conjunction with reviewing and commenting on the entire permit application. Once a RCRA permit is granted, the closure plan in the RCRA permit becomes the facility's "approved" closure plan.

4.2.1.3 Permitting of OB and OD Units Under Subpart X, 40 CFR 264

The Subpart X regulations applicable to permitted OB and OD facilities are located in 40 CFR 264.600 to 264.603. These regulations were promulgated on December 10, 1987. RCRA permit applications for Subpart X units must demonstrate how the units will comply with these regulations, other applicable RCRA regulations, as well as applicable requirements under other laws, both Federal and state.

Subpart X requires that a miscellaneous unit "be located, designed, constructed, operated, maintained and closed in a manner that will ensure protection of human health and the environment." These requirements differ from those developed for other RCRA units (e.g., landfills, surface impoundments, incinerators), in that they establish a standard based on meeting a certain level of environmental performance—a performance standard—rather than on meeting preestablished design and operating standards. For example, Subpart X does not specify minimum technology requirements (e.g., liners, leak detection systems) or monitoring requirements for miscellaneous units, as it does for most other RCRA units, such as landfills.

Performance-based standards are established by EPA (or a state agency, see Sect. 4.2.2) as a result of the permit application and review process, and are based on information provided in the permit application. In addition, as indicated in the preamble to the Subpart X final rule (see 52 FR 46955), the permit applicant is expected to propose the specifications for unit location, design, construction, operation, monitoring, maintenance, closure, and, where applicable, post-closure care within the permit application, Upon review of the application and negotiation with the facility owner or operator, a set of unit-specific location, design, construction, operation, etc., standards will be established that will ensure protection of human health and the environment. The standards established for a particular miscellaneous unit may include those required for other types of RCRA units.

Fig. 4-5 presents an overview of the RCRA Subpart X permitting process. Permitting Subpart X units has proven to be a challenge due to a lack of definitive Subpart X regulatory guidance. Typically, the lead regulatory agency will issue Notices of Deficiency (NODs) as the mechanism for obtaining additional information needed for decisionmaking. NODs have frequently involved closure plan deficiencies and issues. In general, the information included in 1988-vintage Subpart X permit applications did not address many OB/OD issues. This can be attributed to the limited time available to meet the November 8, 1988, Part B permit application deadline after the Subpart X regulations were finalized in December of 1987, and to the lack of regulatory guidance.

Most Army OB/OD units are currently in the regulatory agency review and evaluation stage or the NOD issuance stage of RCRA permitting. Future permitting phases are expected to include negotiating permit conditions, permit decisions, and public notice/meetings. The Army is reevaluating whether closure of OB/OD units (which are in the permitting process or have permits) is warranted based on permitting/permit implementation costs and mission needs. Permit denials by the regulator or closure decisions by the owner/operator will trigger the implementation of RCRA closure and, if applicable, post-closure requirements.

4.2.2 State Authorization

RCRA, like other environmental laws, authorizes states to administer their own programs under the statute. State program requirements must be equivalent to and consistent with Federal program requirements. State program requirements may also be more stringent or extensive than Federal program requirements.

State authorization status is important for two reasons.

- It establishes which regulations are applicable to the closure of OB and OD units: the Federal regulations in 40 CFR 264 and 265, or state-specific RCRA regulations.
- It establishes who the regulator is for the entire RCRA program or for specific aspects of the RCRA program.

As of May 12, 1997, the following states and territories were not authorized to administer their own RCRA programs: Iowa, Alaska, Hawaii, American Samoa, Northern Mariana Islands, Puerto Rico, and the Virgin Islands. In these states and territories only, the Federal regulations in 40 CFR 264 and 265 are applicable to all aspects of OB and OD operations, including closure. In these states and territories, the regulator is the EPA Region in which the state or territory is located.

As the Federal regulations change, RCRA-authorized states must modify their programs to include requirements that are at least equivalent to the Federal requirements. On December 10, 1987, EPA finalized Subpart X regulations. Almost all RCRA-authorized states and one territory (Guam) have adopted at least equivalent Subpart X regulations in their programs. These states do not administer the Subpart X program, however, until EPA authorizes their Subpart X regulations. EPA has authorized 40 states and Guam to regulate Subpart X units in their state/territorial programs. In these states and Guam, state- and territory-specific RCRA regulations are applicable to the closure of interim status and permitted OB/OD units. The state/territory is the regulator.

In the RCRA-authorized states that have not adopted Subpart X regulations, or have adopted Subpart X regulations but these regulations have not yet been authorized by EPA, the situation is more complicated. In these states, there is generally a sharing of responsibility between state regulatory agencies and EPA Regions. In authorized states that have not adopted Subpart X regulations, EPA is handling the permitting of OB/OD units under the Federal Subpart X requirements. In authorized states that have adopted Subpart X regulations but the regulations have not yet been authorized by EPA, the state and EPA Region are cooperating in the permitting of OB and OD units under the Federal Subpart X requirements.

Table 4-1 identifies the regulations and the regulator applicable to the closure of interim status and permitted OB and OD units in each state and territory as of December 31, 1999.

Table 4-1. Regulations and regulators associated with the closure of RCRA OB/OD units, by state or territory

State or territory	Applicable OB/OD regulations	Regulator
Alabama	State	State Regulatory Agency
Alaska	Federal	EPA Region 10
American Samoa	Federal	EPA Region 9
Arizona	State	State Regulatory Agency
Arkansas	State	State Regulatory Agency
California	State	State Regulatory Agency
Colorado	State	State Regulatory Agency
Connecticut	State	State Regulatory Agency
Delaware	State	State Regulatory Agency
District of Columbia	District for Interim Status, Federal for Permitting and Permitted Status	District Government Agency and EPA Region 4
Florida	State	State Regulatory Agency
Georgia	State	State Regulatory Agency
Guam	Territory	Territorial Regulatory Agency
Hawaii	Federal	EPA Region 9
Idaho	State	State Regulatory Agency
Illinois	State	State Regulatory Agency
Indiana	State	State Regulatory Agency and EPA Region 5
Iowa	Federal	EPA Region 7
Kansas	State	State Regulatory Agency
Kentucky	State	State Regulatory Agency
Louisiana	State	State Regulatory Agency

Table 4-1. (Continued)

State or territory	Applicable OB/OD regulations	Regulator
Maine	State for Interim Status, Federal for Permitting and Permitted Status	State Regulatory Agency and EPA Region 1
Maryland	State for Interim Status, Federal for Permitting and Permitted Status	State Regulatory Agency and EPA Region 3
Massachusetts	State for Interim Status, Federal for Permitting and Permitted Status	State Regulatory Agency and EPA Region 1
Michigan	State	State Regulatory Agency
Minnesota	State	State Regulatory Agency
Mississippi	State	State Regulatory Agency
Missouri	State	State Regulatory Agency
Montana	State	State Regulatory Agency
Nebraska	State	State Regulatory Agency
Nevada	State	State Regulatory Agency
New Hampshire	State	State Regulatory Agency
New Jersey	State	State Regulatory Agency
New Mexico	State	State Regulatory Agency
New York	State	State Regulatory Agency
North Carolina	State	State Regulatory Agency
North Dakota	State	State Regulatory Agency
Northern Mariana Islands	Federal	EPA Region 9
Ohio	State	State Regulatory Agency
Oklahoma	State	State Regulatory Agency
Oregon	State	State Regulatory Agency

Table 4-1. (Continued)

State or territory	Applicable OB/OD regulations	Regulator
Pennsylvania	State for Interim Status, Federal for Permitting and Permitted Status	State Regulatory Agency and EPA Region 3
Puerto Rico	Federal	EPA Region 2
Rhode Island	State for Interim Status, Federal for Permitting and Permitted Status	State Regulatory Agency and EPA Region 1
South Carolina	State	State Regulatory Agency
South Dakota	State	State Regulatory Agency
Tennessee	State	State Regulatory Agency
Texas	State	State Regulatory Agency
Utah	State	State Regulatory Agency
Vermont	State	State Regulatory Agency
Virgin Islands	Federal	EPA Region 3
Virginia	State for Interim Status, Federal for Permitting and Permitted Status	State Regulatory Agency and EPA Region 3
Washington	State	State Regulatory Agency
West Virginia	State for Interim Status, Federal for Permitting and Permitted Status	State Regulatory Agency and EPA Region 3
Wisconsin	State	State Regulatory Agency
Wyoming	State	State Regulatory Agency

Source: EPA RCRA/Superfund Hotline; May 12, 1997.

The remainder of this guidance document focuses on Federal regulations and guidance applicable to the closure of OB and OD units. State-specific regulations, guidance, and policies are mentioned when they are more stringent or broader than the Federal requirements, or when they provide information or insight on how the Federal regulations applicable to the closure of OB and OD units are being applied in real-world situations. All regulatory citations are to the Federal regulations unless otherwise mentioned.

4.2.3 Closure Guidance

Besides state and Federal regulatory requirements, state and Federal guidance and policy statements define closure requirements and provide information relevant to the closure of Subpart X units. Appendix E is an annotated bibliography of closure-related documents.

4.2.3.1 Federal Guidance and Policies

The most recent version of the EPA guidance document for Subpart X permit writers was issued in June 1997. It is entitled RCRA 40 CFR Part 264, Subpart X Draft Permit Writers Technical Resource Document (USEPA, June 1997). This document only provides minimal guidance relative to the closure of OB/OD units. However, it does state the need for contingent closure plans to supplement clean closure plans and acknowledges that delay of closure may be warranted for OB/OD units located within impact areas of active military ranges.

EPA's Region 9 published a Checklist for Technical Review of RCRA Part B Permit Application for Subpart X Units (March 1992). It includes portions applicable to the review of closure and post-closure plans. This checklist is currently being used for permit application review by other EPA Regions and states. Owners/operators preparing RCRA permit applications for OB and OD units should ask their regulators if the permit application should follow the format of the Region 9 Subpart X checklist or some other format.

EPA's RCRA Guidance Manual for Subpart G Closure and Post-Closure Care Standards and Subpart H Cost Estimating Requirements (USEPA, 1987b) describes closure and post-closure care requirements in detail. It does not contain information specific to Subpart X units because it was published in January 1987, before the Subpart X rule was finalized.

Additional EPA guidance relevant to OB/OD unit RCRA closure are listed below:

- "Risk-Based Clean Closure" RCRA policy memorandum (USEPA, March 1998).
  - Reaffirms site-specific, risk-based clean closure standards.
  - Clarifies acceptability of fate and transport modeling to support clean closure determinations.
  - New interpretation that confirms acceptability of non-residential exposure assumptions commensurate with expected land use.

+ See Appendix J.4 for additional information.

- RCRA, Superfund & EPCRA Hotline Training Module, Introduction to: Closure/Post-Closure (40 CFR Parts 264/265, Subpart G) (USEPA, July 1997).

    + Summarizes RCRA closure requirements
    + Includes closure timetable figures.
    + See Appendix J.6 for additional information.

- "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Actions and Underground Storage Tank Sites" (USEPA, November 1997).

    + Defines role of natural attenuation in remediation.
    + Identifies implementation criteria for natural remediation.
    + Specifies performance monitoring requirements.
    + See Appendix J.7 for additional information.

- Management of Remediation Waste Under RCRA (USEPA, October 1998c)

    + Clarifies remediation waste management policies.

    + Facilitates greater remediation waste management flexibility.

    + Companion chart provides information on the RCRA regulations and policies that most often affect remediation waste.

    + See Appendix J.8 for additional information.

- "Environmental Fact Sheet: Post-Closure Permit Amendment Addresses Corrective Action" (USEPA, October 1998b).

    + Provides a summary of "Standards Applicable to Owners and Operators of Closed and Closing Hazardous Waste Management Facilities: Post-Closure Permit Requirements and Closure Process" (USEPA, October 1998a).

    + Expands options to address site-specific environmental needs at facilities that need post-closure care.

    + Facilitates coordination of site-specific RCRA closure and corrective action requirements.

+ The Fact Sheet prepared by EPA on this amendment is provided in Appendix J.9.

+ An Army fact sheet on this amendment is provided in Appendix J.10.

4.2.3.2 State Guidance and Policies

A survey was performed in October 1995 to determine whether states had specific guidance or policies regarding the closure of RCRA OB and OD units. The results of this survey are reported in Appendix F. In general, the survey identified specific state guidance and policies concerning how the closure environmental performance standard should be achieved. For example, the survey shows that states tend to have specific guidance and policies pertaining to:

- performing risk assessment,
- setting cleanup standards,
- managing investigation-derived waste, and
- sampling and analysis techniques for soil sampling.

These topics are addressed in Sects. 6 through 9 of this document.

4.3 RCRA CLOSURE REQUIREMENTS

Closure regulations are applicable to all interim status OB and OD units regulated under 40 CFR 265 and all permitted OB and OD units regulated under 40 CFR 264. This section addresses the following topics (see Fig. 4-6):

- Closure standards,
- Closure plan content,
- Closure plan modifications, and
- Closure milestones.

The October 1998 RCRA closure/post-closure amendments facilitate greater regulatory flexibility (e.g., use of corrective action or alternative enforcement processes). Therefore, the lead regulatory agency should be contacted regarding potential alternatives to the RCRA corrective action process. However, the RCRA closure requirements still need to be addressed if an alternative enforceable process/document are used.

4.3.1 Closure Standards

The regulations specifying how OB and OD facilities must be closed have two parts: the general closure performance standard and the unit-specific standard for OB and OD units (see Fig. 4-7).

4.3.1.1 General Closure Performance Standards

The closure performance standards are applicable to all hazardous waste TSDFs. The closure performance standards under 40 CFR 265, Subpart G, for interim status facilities and 40 CFR 264, Subpart G, for permitted facilities are identical. They require the owners or operators of hazardous waste management facilities to close the facility in a manner that:

- minimizes the need for further maintenance after closure;

- controls the post-closure escape to surface waters, groundwater, or the atmosphere of hazardous waste, hazardous constituents, leachate, contaminated run-off, and hazardous waste decomposition products; and

- complies with applicable unit-specific closure requirements.

4.3.1.2 Unit-Specific Closure Standards

Unit-specific closure requirements are the second part of the closure regulations that must be met by OB and OD units.

- The unit-specific requirements applicable to interim status OB and OD units are located in 40 CFR 265, Subpart P and Subpart N.

- The unit-specific requirements applicable to permitted OB and OD units are located in 40 CFR 264, Subpart X.

The 40 CFR 265, Subpart P requirements applicable to interim status thermal treatment (most applicable category for OB/OD units) units require the removal of all hazardous waste and hazardous waste residues (including but not limited to ash) from the thermal treatment process or equipment at closure. This type of closure is known as clean closure.

EPA has issued a March 16, 1998 memorandum that confirmed and clarified guidance on risk-based clean closure for RCRA units (USEPA, March 1998). A copy of this guidance memorandum is provided in Appendix J.4. Risk-based clean closure standards are determined on a site-specific basis but must ensure that constituents left in place do not endanger human health and the environment. Additional discussion of the EPA risk-based clean closure guidance is presented in Sec. 2.1.1.2.

Unit-specific requirements applicable to the closure of interim status landfills are located in 40 CFR 265, Subpart N. These regulations require that landfills be covered with a final cover designed and constructed to:

- provide long-term minimization of migration of liquids through the closed landfill;

- function with minimum maintenance;

- promote drainage and minimize erosion or abrasion of the cover;

- accommodate settling and subsidence so that the cover's integrity is maintained; and

- have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present (40 CFR 265.310(a)(1)-(5)).

However, the October 1998 RCRA closure/post-closure amendments facilitate greater regulatory flexibility (e.g., use of corrective action or alternative enforcement processes as discussed in Sect. 4.1) for closure with waste in place. Therefore the lead regulatory agency should be contacted regarding potential alternatives to the RCRA closure process.

The unit-specific requirements applicable to permitted OB and OD units are located in 40 CFR 264, Subpart X. These regulations state that permits for miscellaneous units must include requirements (including closure requirements) that will ensure protection of human health and the environment and are appropriate for the miscellaneous unit being permitted (40 CFR 264.601). This regulatory language provides permit writers with a great deal of latitude to determine appropriate closure requirements. The preferred closure approach is typically risk-based clean closure for OB/OD units. As discussed in Sect. 4.1, the October 1998 closure/post-closure amendments also facilitate the application of RCRA corrective action as an alternative clean closure process (also applicable to closure with waste in place), provided that certain prerequisite conditions are met.

4.3.2 Closure Plan Content

Closure plan requirements applicable to all types of hazardous waste management facilities are located in 40 CFR 265.112 for interim status facilities and 40 CFR 264.112 for permitted facilities (see Fig. 4-8). These requirements concern the need to have written closure plans that are available to the regulator and the contents of closure plans. If it is apparent that an OB or an OD unit cannot clean close, a closure plan addressing closure with waste in place would be warranted. However pursuant to the October 1998 closure/post-closure amendments alternative enforceable closure processes/documents may be applicable on a case-by-case basis.

EPA Subpart X permit writers guide states that a permit application must (in addition to the closure plan) also include a contingency plan to close the unit with waste in place if there is the potential that the unit cannot be clean closed. As previously discussed many OB/OD units are expected to produce clean closure based on risk-based cleanup criteria. Therefore, OB/OD units that intend to implement a risk-based clean closure plan should also submit a contingent closure plan (i.e., to close with waste in place if necessary).

Interim status OB and OD units are required to have written closure plans for OB and OD units at the facility. Until closure is completed, a copy must be furnished to the regulator on request, including request by mail. If the closure plan is not approved, it must be made available to the regulator during site inspections (40 CFR 265.112(a)). (When an OB or OD unit closes while it is still in interim status, the closure plan must be "approved" by the regulator before closure can occur. An interim status OB or OD facility with a closure plan that has not been approved by the regulator for a specific closure is not approved.)

Permitted OB and OD units submit written closure plans with their RCRA permit applications. Until closure is completed, the most recent copy of the approved closure plan (or plans) must be furnished to the regulator on request, including request by mail (40 CFR 264.112(a)).

Except for cross-references, regulations describing the required contents of closure plans for interim status and permitted facilities are identical. These regulations are located in 40 CFR 265.112(b) for interim status facilities and 40 CFR 264.112(b) for permitted facilities. Sect. 9 describes how to prepare closure plans meeting these regulations.

4.3.3 Closure Plan Modifications

Closure plans (or alternative enforceable closure documents pursuant to the October 1998 closure/post-closure amendment) must be modified whenever:

- changes in operating plans or facility design affect the closure plan,
- there is a change in the expected year of closure, or
- in conducting partial or final closure activities, unexpected events require a modification of the closure plan (40 CFR 264.112(c)(2) and 265.112(c)(1)).

Fig. 4-9 summarizes requirements applicable to notifying regulators of required closure plan modifications. Closure notifications for alternative enforceable closure processes/documents may be determined on a case-by-case basis.

For interim status units with closure plans that have not been approved, the plans may be modified at any time prior to notification of the regulator of partial or final closure.

For interim status units with approved closure plans and permitted units, requirements affecting the timing of a closure plan amendment are related to the reason for the amendment.

- If the closure plan has to be amended due to a proposed change in facility operation or design, a request must be submitted to the regulator at least 60 days prior to the proposed change (40 CFR 264.112(c)(2)-(3) and 265.112(c)(2)-(3)).
- If the closure plan has to be amended due to the occurrence of an unexpected event affecting closure, a request to authorize the change and a proposed amended plan must be submitted to the regulator:
    - no later than 30 days after the unexpected event occurs if the event occurs during closure, or
    - no later than 60 days after the unexpected event occurs if the event does not occur during closure.

Similarly, if a closure plan has to be amended because a unit that had intended to clean close will close as a landfill, a proposed amended plan must be submitted to the regulator no later than 30 days after the decision to close as a landfill has been made if the decision is made during the closure process, or no later than 60 days after the decision to close as a landfill has been made if the decision is before closure begins (40 CFR 264.112(c)(2)-(3) and 265.112(c)(2)-(3)).

If a closure plan amendment involves events occurring during partial or final closure, the creation of new landfill units as part of closure, or the creation of new hazardous waste management units to be used temporarily during closure, the request for an amendment must be evaluated by the regulator using the public notice and comment procedures described in 40 CFR 265.112(c)(4) for interim status facilities and 40 CFR 264.112(c)(4)) for permitted facilities. These procedures require the regulator to:

- provide the public with the opportunity to comment on the closure plan within 30 days by placing a notice in a newspaper;
- hold a public meeting, if necessary, to clarify closure plan issues; and
- approve, modify, or disapprove the plan within 90 days following receipt.

Closure plans may be modified by owners/operators of permitted facilities for any reason; however, modifications that are not related to changes in operating plans or facility design that affect the closure plan, a change in the expected year of closure, or unexpected events during closure require a RCRA permit modification. Federal RCRA regulations define three classes of permit modifications and describe procedures for obtaining them.

- Class 1 modifications are the least substantive permit changes. The regulatory requirements for obtaining Class 1 modifications involve minimal regulator oversight and public notification/participation. Changes to a closure plan that are Class 1 permit modifications include:
    - changes in the estimate of maximum extent of operations or maximum inventory of waste onsite at any time during the active life of the facility;
    - changes in the closure schedule for any unit;
    - changes in the final closure schedule for the facility or extension of the closure period;
    - changes in the expected year of final closure, where other permit conditions are not changed, and
    - changes in procedures for decontamination of facility equipment or structures.

- Class 2 modifications are substantive permit changes needed to maintain a facility's capability to manage wastes safely or to conform to new requirements. The regulatory requirements for obtaining Class 2 modifications involve considerable regulator oversight and public notification/participation. Changes to a closure plan that are Class 2 permit modifications include:

  - changes in the closure plan resulting from unexpected events occurring during partial or final closure that are not Class 1 or Class 3 modifications, and

  - addition of certain new units (i.e., waste piles meeting requirements of 40 CFR 264.250(c), tanks, or containers) to be used temporarily for closure activities.

- Class 3 modifications are the most substantive permit changes, as they significantly alter the facility or its operations. The regulatory requirements for obtaining Class 3 modifications involve considerable regulator input, public notification/participation, and adherence to the administrative permitting procedures applicable to the processing of applications for full RCRA permits in 40 CFR 124. Changes to a closure plan that are Class 3 permit modifications include:

  - creation of a new landfill unit as part of closure, and

  - addition of certain new units (i.e., waste piles not meeting the requirements of 40 CFR 264.250(c), surface impoundments or incinerators) to be used temporarily for closure activities.

Regulations applicable to the modification of RCRA permits are located in 40 CFR 270.

4.3.4 Closure Milestones

Significant RCRA closure milestones include (see Fig. 4-10):

- notification of closure,
- time allowed for closure activities,
- certification of closure, and
- survey plat and deed notation.

The period from notification of closure to certification of closure ranges from several months to several years, depending on the complexity of the site-specific closure process. An overview of the closure timetable for units with approved closure plans is provided in Fig. 4-11 and for units without approved closure plans in Fig. 4-12. The closure timetable for alternative enforceable closure processes/documents may be determined on a case-by-case basis.

RCRA requirements for notification of closure (40 CFR 264.112 and 265.112) and time allowed for closure activities (40 CFR 264.113 and 265.113) are specified for specific types of units. However, requirements for miscellaneous units (including OB/OD units) are not specified. The closure schedule for landfill units (as well as other land-based RCRA units) may be applicable to some OB/OD units that close with waste in place.

However, pursuant to the October 1998 closure/post-closure amendments alternative enforceable closure processes may be applicable that facilitate a more flexible closure schedule. EPA has recognized that the original RCRA requirements (contemplated in 1982) for closure timeframes in many cases may not be adequate where the closure is a cleanup activity, rather than capping or waste removal activities. This EPA opinion is included in the preamble to the recent post-closure permit amendment (USEPA, October 1998a). EPA expects that this amendment will also allow site-specific flexibility for timeframes for some of the complex closure cases. Therefore, it is recommended that the lead regulatory agency be contacted to determine site-specific closure schedule requirements.

4.3.4.1 Notification of Closure

Notification of closure requirements are summarized in Figs. 4-11 and 12. Submittal of a closure plan serves as the notification process for interim status and other unpermitted units. However, it should be noted that RCRA regulations are silent regarding closure notification for interim status thermal treatment units (e.g., OB/OD units that clean close) and permitted miscellaneous units (e.g., OB/OD units) that clean close. Therefore, the lead regulatory agency should be consulted.

Owners or operators may decontaminate, dismantle, and dispose of burn pans or other equipment at an OB unit without these activities' triggering closure notification requirements. EPA regulations allow the owner or operator to remove hazardous waste and decontaminate or dismantle equipment, in accordance with the closure plan, any time before or after notification of partial or final closure (40 CFR 264.112(e) and 265.112(e)).

The date on which closure is expected to begin, which triggers the closure notification requirement, is either:

- no later than 30 days after the date on which the OB or OD unit received the known final volume of hazardous wastes for treatment, or

- one year after the date of receipt of the most recent volume of hazardous waste (40 CFR 264.112(d)(2) and 265.112(d)(2)).

The regulator may extend the one-year time limit if the facility can demonstrate to the regulator that the facility has the capacity to receive additional hazardous wastes and that all steps have been or will be taken to prevent any threats to human health and the environment.

Other triggers for the closure of interim status OB and OD units are:

- termination of interim status (without receiving a permit); or
- issuance of a judicial decree or final order under Sect. 3008 of RCRA to cease receiving hazardous waste or to close. (Under these circumstances, interim status OB and OD units that do not have approved closure plans must submit them to the regulator within 15 days.)

Similarly, triggers for the closure of permitted units include:

- termination of the permit, or
- issuance of a judicial decree or final order under Sect. 3008 of RCRA to cease receiving hazardous waste or to close.

Requirements applicable to notification of closure do not apply to OB and OD units forced to close because of:

- termination of interim status (without receiving a permit),
- termination of a permit, or
- issuance of a judicial decree or final order under Sect. 3008 of RCRA to cease receiving hazardous waste or to close.

The lead regulatory agency should be consulted for these cases.

4.3.4.2 Time Allowed for Closure Activities

Because the closure of OB and OD units will generally involve the performance of environmental and risk assessments, it is unlikely that the closure of these units can be accomplished within the RCRA closure timeframes (see Figs. 4-11 and 12) following regulator notification of closure. Consequently, closure plans for OB and OD units should include a justification (e.g., closure activities will, of necessity, take longer than specified in 40 CFR 264.113(b) and 40 CFR 265.113(b) and that human health and the environment would not be endangered by the closure extension) for extending these deadlines.

EPA has recognized that the current RCRA timeframes may, in some cases, not be adequate where the closure is a cleanup activity, rather than the more straight forward capping or waste removal activities (USEPA, October 1998a). EPA expects that the RCRA post-closure permit amendments (October 1998) will, in some cases, also facilitate greater site-specific flexibility for closure timeframes. (Refer to Sec. 4.4.1 for additional information on the October 1998 post-closure permit amendments).

4.3.4.3 Certification of Closure

Once closure activities have been concluded, the owner or operator and an independent registered professional engineer must sign a certification stating that closure activities were conducted in accordance with the approved closure plan. (An independent professional engineer is a professional engineer who is not a direct employee [i.e., not on the payroll] of the facility owner or operator.) The certification must be submitted to the regulator by registered mail within 60 days following completion of closure (see Fig. 4-13).

The regulations do not specify if the closure certification must be submitted after the closure of individual OB or OD units (i.e., after partial closure) or after final closure of all OB and OD units. The closure plan should specify when the facility plans to provide the certification. In general, the more extensive the activities associated with a partial closure, the more important it is to provide the closure certification after partial closure.

The regulations require that documentation supporting the professional engineer's certification be furnished to the regulator on request. Supporting documentation for clean-closing facilities may include sampling, testing, and analysis results that prove that the closure was complete and that the facility is "clean" according to the criteria provided in the closure plan. Because of the many technical factors involved in demonstrating clean closure, this documentation will probably be an extensive report. If he or she is not satisfied with this information, the regulator may request additional sampling information, statistical analyses, and in some cases, additional soil removal.

4.3.4.4 Survey Plat and Deed Notation

After the closure of OB and OD units where wastes will remain in place after closure (i.e., that do not clean close), a survey plat must be submitted to the local zoning authority (or the authority with jurisdiction over local land use) and to the regulator (see Fig. 4-14). The plat must identify the dimensions of the OB or OD units with respect to permanently surveyed benchmark and must be prepared by a professional land surveyor. It must be submitted no later than the certification of closure for the unit (40 CFR 264.116 and 265.116).

Within 60 days after the certification of closure for each unit where wastes remain in place after closure (40 CFR 264.119(b) and 40 CFR 265. 119(b):

- A record of the type, location, and quantity of hazardous waste remaining in the unit must be filed with the local zoning authority (or the authority with jurisdiction over local land use) and to the regulator; and

- A notation on the deed to the facility property must be recorded noting the following information for potential purchasers:

  - the land has been used to manage hazardous waste;

  - use of the land is restricted by regulation; and

  - a survey plat and record of wastes have been filed with the land use authorities and the regulator.

In addition, after certification of closure of the first and last OB and OD units where wastes will remain in place after closure, a signed certificate must be submitted to the regulator stating that the deed notation has been recorded pursuant to 40 CFR 264.119(b)/40 CFR 265.119(b).

4.4 POST-CLOSURE CARE

Post-closure care regulations are applicable to interim status and permitted OB and OD units that do not clean close (where wastes will remain in place after closure). These regulations are included in 40 CFR 265.117-120 for interim status facilities and 40 CFR 264.117-120 for permitted facilities.

Post-closure care regulations define:

- post-closure permits,
- post-closure care activities,
- the length of the post-closure period,
- the contents and methods of amending post-closure plans, and
- requirements for post-closure notices and certificates of completion of post-closure care.

4.4.1 Post-Closure Permit and Alternative Enforcement Documents

The need for a post-closure permit for closure with waste in place is specified in 40 CFR 270(c). RCRA regulations do not directly identify the applicability of post-closure permit requirements to miscellaneous units. However, RCRA does specify that landfills and other land-based units that close with waste in place would require a post-closure permit. Those OB/OD units that close with waste in place, therefore, are also considered to need a post-closure permit.

In the case of land-based units with operating permits, the RCRA permit typically incorporates the closure plan and applicable site-specific post-closure requirements. For OB/OD units the EPA Subpart X permit writers guide states that contingent closure plans (to close a landfill and to specify post-closure care) must be provided in the operating permit application if there is the potential the unit cannot achieve clean closure. Therefore, frequently the operating permit may also serve as the post-closure permit, as necessary.

The post-closure permit for interim status, land-based units is typically issued after completion of closure. However, the post-closure permitting process for these units achieves the following regulatory objectives:

- Necessitates the submittal of a post-closure permit application that includes extensive information on the hydrogeological characterization of the unit and extent of any groundwater contamination.
- Imposes 40 CFR 264 standards including Subpart F groundwater monitoring requirements (applicable to permitted facilities in lieu of 40 CFR 265 standards as applicable to interim status facilities).

- Requires facility-wide corrective action, as necessary.

- Identifies the public involvement process that includes written notification to the public when the permit application/post-closure plan/draft permit are available for public comment and provides the opportunity for a public hearing.

EPA has promulgated "Standards Applicable to Owners and Operators of Closed and Closing Hazardous Waste Management Facilities: Post-Closure Permit Requirement and Closure Process, Final Rule" (Federal Register: October 22, 1998, Vol. 63, No. 204). A summary of this amendment to 40 CFR 264, 265, 270, and 271 is provided in Appendix J (USEPA, October 1998b).

The closure/post-closure amendment addresses the following:

- Alternatives to post-closure permits.
- Remediation requirements for land-based units with releases to the environment.
- Post-closure Part B permit application submission requirements.

The October 1998 amendment allows regulators flexibility to issue a post-closure permit to a facility or to impose the same regulatory requirements in an enforceable non-permit authority in lieu of a post-closure permit. These alternative enforcement mechanisms may include RCRA corrective actions, CERCLA, or state orders. This alternative approach provides a somewhat different approach for public involvement compared with the post-closure permit requirements. The alternative enforcement documents must provide for public involvement at the following three key stages:

- When the lead regulatory agency becomes involved in remediation at the facility as a regulatory or enforcement matter (e.g., corrective action).

- Remedy selection.

- Before making a decision that corrective action at the facility is completed.

The provisions for alternatives to post-closure permits are applicable to non-permitted land disposal facilities that close with waste in place. It is recommended that these alternatives to the post-closure permit be pursued because this approach should save the Army paperwork, time, and money.

Part B permit application information requirements have been clarified in the amendment. These information submittal requirements are also applicable to alternative enforcement mechanisms (in lieu of a post-closure permit). Submittal requirements include the following input:

- Groundwater characterization and monitoring data,
- Long-term, post-closure care and monitoring systems,
- Information on solid waste management units (SWMUs) and possible releases, and
- Additional site-specific data as may be needed by the lead regulatory agency.

The October 1998 amendment also allows regulators to replace the closure remediation and groundwater monitoring requirements at certain hazardous waste units with similar site-specific requirements developed through the RCRA corrective action process. These alternative remediation provisions are applicable to both permitted and non-permitted facilities that meet all of the following conditions:

- The closure unit must be situated among SWMUs and/or areas of concern (AOCs).
- Both the closure unit and SWMUs/AOCs are likely contributors to a release.
- Corrective action process is deemed protective of human health and the environment.
- Cleanup remedy will satisfy RCRA closure performance standards.

For interim status facilities, these alternative standards would be specified in an alternative enforcement document. For permitted facilities the alternative standards would be specified in the permit or alternative enforcement document. These alternative mechanisms facilitated by the October 1998 closure/post-closure amendment are expected to provide greater flexibility to the Army in the remediation of releases from OB/OD and other RCRA units.

The adoption status of the October 1998 closure/post-closure amendment may vary by state. Therefore, the lead regulatory agency should be contacted to determine site-specific applicability.

4.4.2 Post-Closure Care Activities

Post-closure care activities must include all activities necessary to monitor and maintain waste containment systems. These activities will generally include:

- groundwater and soil monitoring; and

- maintenance activities including routine facility inspections, maintenance of waste containment systems (e.g., mowing, fertilizing, replacement of soil lost to erosion and all other activities necessary to prevent liquids infiltration of the cover); maintenance of monitoring systems (e.g., replacing or repairing monitoring wells, seals, pumps); maintenance of the security system (e.g., replacement of sections of fences due to normal wear or severe weather conditions).

4.4.3 Post-Closure Care Period

The post-closure care period lasts for 30 years unless the length of the period is increased or decreased by the regulator. In determining if a longer period is required or a shorter period is adequate, the regulator will consider site-specific facility conditions. If you believe a shorter period may be justified based on a low risk potential, provide a justification for the shorter period in your post-closure plan submitted with your permit application.

4.4.4 Post-Closure Plans

Post-closure plans (or alternatives enforceable documents pursuant to the October 1998 closure/post-closure amendments) for OB/OD units to close with waste in place need to be submitted to the lead regulatory agency at least 180 days before the start of closure activities. Regulations applicable to the preparation of post-closure plans specify that they must address the activities that will be carried on after the closure of each unit where wastes will remain in place after closure and include:

- a description of planned monitoring activities and the frequencies at which they will be performed during the post-closure period;

- a description of planned maintenance activities and the frequencies at which they will be performed to ensure the integrity of the cap and final cover or other containment systems and the function of monitoring equipment; and

- the name, address, and phone number of the person or office to contact about the facility during the post-closure care period (40 CFR 270.14(b)(13), 264.118(b), and 265.118(b)).

Post-closure plans must be modified whenever:

- changes in operating plans or facility design affect the post-closure plan; or
- events that occur during the active life of the OB or OD units covered by the plan, including partial and final closures, affect the post-closure plan (40 CFR 264.118(d)(1) and 265.118(d)(1)).

Post-closure plan modification deadlines are addressed in 40 CFR 265.118(d) for interim status facilities and 264.118(d) for permitted facilities.

4.4.5 Certification of Completion of Post-Closure Care

Within 60 days after completion of the 30-year post-closure care period for each OB or OD unit, certification that post-closure care was completed in accordance with the approved post-closure plans must be submitted to the regulator. Like the closure certification, the post-closure certification must be signed by the owner or operator and an independent registered professional engineer. The independent registered professional engineer will have to rely on a review of the documents generated by OB and OD units during the post-closure care period including inspection reports, groundwater monitoring results, invoices for maintenance activities, etc.

As with certification of closure, the regulations also require that documentation supporting the professional engineer's certification be furnished to the regulator on request. Installations should maintain any supporting documentation (information regarding activities conducted during inspections, field reports documenting site visits, in-house records) until the regulator accepts the post-closure certification.

4.5 RELATED REGULATORY REQUIREMENTS

Related regulatory requirements include (see Fig. 4-15):

- RCRA Munitions Rule
- Requirements applicable to the transfer/sale of land with OB/OD units (Army Regulations, RCRA, CERCLA, DOD Draft Final Policy on Responsibility for Additional Environmental Cleanup after Transfer of Real Property)
- Requirements applicable to wetlands.

4.5.1 RCRA Munitions Rule

On February 12, 1997, EPA promulgated the final Munitions Rule. The rule identifies when conventional and chemical military munitions become hazardous waste under RCRA. Munitions subject to RCRA hazardous waste regulations must be treated, stored, and disposed of in RCRA-regulated units that meet all applicable requirements, including the requirements applicable to closure and post-closure care that are described in this document.

4.5.2 Transfer/Sale of Land with OB/OD Units

DOD is engaged in a major downsizing and is in the process of closing 70 major installations in the United States. Additional bases will be closed and realigned in the future. Base closure and realignment will involve the closure of currently operating OB and OD units. Further, economic redevelopment efforts in base closure communities may involve the sale or transfer of land that formerly housed OB or OD operations. This section discusses regulatory considerations applicable to the transfer or sale of land containing operating or closed OB or OD units.

4.5.2.1 Army Regulations

Army Regulation (AR) 405-90 sets forth authorities, responsibilities, policies, and procedures for the disposal of military and industrial real estate under the custody and control of the Department of the Army worldwide. Chapter 2-2 of this regulation, Contaminated Real Property, describes requirements applicable to real property contaminated with material that may pose explosive hazards, or with substances posing chemical, biological, or radioactive hazards. According to these requirements, the Department of the Army may not transfer accountability and control of property posing an explosive hazard until the property is rendered "innocuous". The Army policy regarding this issue is still evolving.

Property posing chemical, biological, or radioactive substance risks must also be decontaminated before property is transferred from Department of the Army control. Decontamination is defined as "the process of reducing contamination to an acceptable level or completely eliminating its presence." (AR 405-90, Chapter 2-2)

4.5.2.2 RCRA

The sale or transfer of DOD land with operating OB or OD units is unlikely but possible. In the event that this occurs, installation managers should remember that new owners or operators will have to demonstrate compliance with financial assurance requirements for closure unless, like DOD, the new owners or operators are exempt from these requirements. (They will also have to demonstrate compliance with financial responsibility requirements for post-closure care and third-party liability.) Until the new owner or operator demonstrates compliance with financial responsibility requirements, DOD will remain responsible for the costs of closure, post-closure care, and third-party liability. Consequently, installations should evaluate the financial viability of new owners or operators before selling land with operating OB or OD units.

The closure regulations described in Sect. 4.3.4.4 (Survey Plat and Deed Notation) were developed with the explicit purpose of informing prospective buyers of the former uses of closed RCRA hazardous waste management units.

4.5.2.3 CERCLA

Regulations have also been promulgated under CERCLA to inform prospective buyers of the former uses of possibly contaminated property. These regulations, located in 40 CFR 373, require departments, agencies, and instrumentalities of the United States to provide notice of the storage, release, or disposal of hazardous substances in contract for the sale or transfer of real property owned by the United States. These regulations are applicable to OB and OD units where hazardous substances have been released in quantities greater than or equal to the substance's CERCLA reportable quantity found at 40 CFR 302.4 (see 40 CFR 373.2(a) to (c)).

If land where hazardous substances were stored, released, or disposed of is to be sold, transferred, or leased, DOD is required to determine whether the land is contaminated. This determination is made on the basis of an environmental baseline survey. If the property is found to be uncontaminated, the deed for the sale or transfer of the property must contain:

- a covenant warranting that any response action or corrective action found to be necessary after the date of sale or transfer shall be conducted by the United States, and

- a clause granting the United States access to the property in any case in which a response action or corrective action is found to be necessary on the property or on an adjoining property (see Sects. 120(h)(1)-(5) of CERCLA).

4.5.2.4 Effect of Fulfilling RCRA and CERCLA Requirements Associated with Property Sale or Transfer

The effect of fulfilling the RCRA and CERCLA notice requirements associated with property sale or transfer that are described above is to alter the post-transaction rights and remedies of DOD and buyers or holders of DOD properties. DOD's fulfillment of these requirements makes it more difficult for buyers or holders to assert legal claims against the Department because they were not informed of the former uses, restrictions on future uses, and liabilities associated with these properties.

The remediation, corrective action, deed restrictions, and covenants required under CERCLA provide protection against future environmental liability costs to buyers of DOD property. Congress added these provisions to CERCLA hoping that this protection to buyers would serve to facilitate the sale, transfer, and redevelopment of Federal property, particularly military bases.

4.5.2.5 DOD Policy Governing Additional Cleanup After Transfer

DOD released a policy on additional cleanup after land transfer in July 25, 1997. The policy describes the circumstances under which DOD would perform additional cleanup on DOD property that is transferred by deed to any person or entity outside the Federal government. According to this policy, DOD would return to do additional cleanup if:

- the remedy failed to perform as expected, a determination is made that a remedy put in place prior to the transfer is no longer protective of human health, and the environment, or

- additional contamination that is inconsistent with the established remedy and is attributable to DOD's activities is discussed after transfer.

Circumstances where DOD would not return to do additional cleanup include those where additional remedial action is necessary to facilitate a use prohibited by deed restriction or other appropriate institutional control. It is DOD's position that such additional remedial action is not necessary within the meaning of CERCLA Section 120(h)(3).

4.5.3 Requirements Applicable to Wetlands

OB and OD operations may be located in areas that are wetlands, or such operations may have resulted in the incidental creation of wetlands. Closure and post-closure plans for OB and OD units located in wetlands should incorporate requirements imposed by wetlands regulations and permits (see Section 404 of the Clean Water Act) administered by the U.S. Army Corps of Engineers. For additional information, contact your Corps District Office. In addition, individual states may have wetlands requirements that should be considered in closure and post-closure plans.

Federal wetlands regulations do not specifically address the question of whether wetlands created as an incidental result of OB and OD operations must be permitted by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act. In these situations, the Corps tends to rely on the judgment of the technical specialist assigned to evaluate the situation. The recommendations of the technical specialist could influence the strategy to be followed to achieve closure; such recommendations should consequently be considered in developing closure and post-closure plans.

5. SPECIFIC CLOSURE/POST-CLOSURE PLAN BACKGROUND INFORMATION REQUIREMENTS

RCRA regulations specify the required contents of the closure plan but do not require the owner or operator to adhere to any particular format when developing it. 40 CFR §§ 264.112 (b) and 265.112(b) describe the minimum information that needs to be included in a closure plan. However, these regulations do not specify general background information that may be helpful to the regulatory agencies. Therefore, the following background sections are recommended for inclusion in closure/post-closure plans (see Fig. 5-1):

- Permitting background
- Facility description
- Environmental setting

This information should also be provided in alternative enforceable documents if corrective action or an alternative closure process is used.

Individual permit writers and regulatory agencies, however, may have different requirements. For example, some states (e.g., Georgia and Tennessee) have required only minimal information, while others (e.g., Kentucky) have required whole portions of the permit application to be restated.

5.1 PERMITTING BACKGROUND

The general permitting background information for the facility should be based on information typically included in the permit application. The following is a list of items which should be addressed (see Fig. 5-2):

- General site history
- RCRA permitting history
- CERCLA activity
- RCRA/CERCLA/BRAC integration

5.1.1 General Site History

General information on the installation should be provided, including: site name, location, size, the date the facility began operation, and its current and historical mission, as well as a description of the types of activities that have been conducted there. The reason the facility has decided to close its units should also be given. The BRAC process has been the primary basis for OB/OD closure decisions, but other reasons could include USAEC's OB/OD consolidation study of 1994 and permit denials by regulatory agencies.

5.1.2 RCRA Permitting History

The RCRA permitting history discussion should include background information on the RCRA activities that have occurred at the installation. The types of information that should be included are the chronology of RCRA permitting history, including the date the installation submitted a RCRA Part B Permit Application for the OB/OD unit, the receipt of any NODs from the regulatory agency for the RCRA Part B submittal, and a brief discussion of other RCRA units at the installation and their permitting status. Any RCRA issues that are unique to the installation also need to be mentioned. In addition, all orders and consent agreements should be identified and discussed (including Federal Facilities Compliance Agreements [FFCAs]). Also, all RCRA corrective action activities need to be discussed, including submission of RFI reports, Corrective Measures Study, and Corrective Measures Implementation.

5.1.3 CERCLA Activity

CERCLA activities should be discussed if the installation is on the National Priorities List (NPL). All CERCLA investigations completed should be identified and discussed, especially if they pertain to the unit or units to be closed. The types of investigations that should be discussed include preliminary assessments, site investigations, RI/FS, remedial designs, remedial actions, and removal actions. It may also be useful to discuss any supporting documentation such as quality assurance project plans and community relations plans.

5.1.4 RCRA/CERCLA/BRAC Integration

RCRA/CERCLA/BRAC integration may not be applicable for all installations. However, if applicable, the coordination of RCRA/CERCLA/BRAC requirements and actions is a major closure goal. This coordination is especially important to installations where RCRA/CERCLA/BRAC activities are occurring concurrently with closure of the OB/OD unit. Plans to use any of the data and analyses generated under the CERCLA activities to support the OB/OD unit closure plan should be discussed. The potential for cost avoidance can be significant (especially if site investigation data can serve multiple needs). Extensive interaction with the regulatory agencies will be required to ensure that this process goes smoothly.

5.2 FACILITY DESCRIPTION

Facility description information to be presented in the closure plan should include the following (see Fig. 5-3):

- Facility location and size
- Description of unit to be closed
- Unit operation: history, operating procedures, and disposal records

If the facility has an existing RCRA permit or is in the process of developing a permit application, the majority of the facility description information will be available from other sections of the RCRA Part B permit or permit application. However, it is useful to include a summary of this information in the closure plan. At a minimum, the closure plan should reference where in the permit (or permit application) such information may be obtained. This information must be included if the closure plan is a stand-alone document. The general description of the facility should be straightforward, brief, and general.

5.2.1 Facility Location and Size

The closure plan should discuss the location of the facility in relation to the closest city or municipality, as well as the county or counties in which the facility is located. The overall size of the installation should also be identified. Generally, two maps should be provided: a regional location map showing the location of the facility in the state, and a local map identifying the facility and the surrounding areas (including major highways).

5.2.2 Description of Unit to Be Closed

General information on the location, size, and design of the Subpart X unit should be included in the closure plan. The location of each OB/OD unit within the installation should be included. A map should also be included showing the location of the unit within the installation and access roads.

The size of the unit should be specified in the closure plan. In instances where the unit has been divided into an active zone and a safety buffer zone, the size and locations of the active portion relative to the rest of the unit should be identified. Fencing and other security measures used for the OB/OD unit should also be discussed.

For OB units using burn pans or trenches, the physical characteristics, construction materials, and dimensions of the unit should be provided as well as engineering drawings of any fabricated devices. The lining material within and below the burn pans should also be provided. Engineering plans and drawings should be provided.

For OD operations, the physical characteristics, materials, and dimensions of the unit should be provided. In addition, a description of the pits, craters, and other OD features at the unit should also be provided.

The operating history of the OB/OD unit should be discussed. Information on past and present operating procedures, design modification, and previous uses and past waste management practices at the unit should be addressed.

5.2.3 Unit Operation

The history and operating procedures of the unit and the disposal records should be summarized. The dates of operation and any past uses of the OB/OD units should be discussed. The implementation of regular inspections, if appropriate, should also be discussed.

Disposal records provided should include the type and quantity of ordnance treated. These data are usually compiled in tables for easy presentation. Completed forms such as DA Form 581 (Request for Issue and Turn-In of Ammunition) provide a reliable source of disposal information.

5.3 ENVIRONMENTAL SETTING

The environmental setting (both installation specific and unit specific) needs to be discussed for general background information and as input to the development of risk-based cleanup criteria (discussed in Sect. 8). The types of information that typically should be included (see Fig. 5-4) are:

- Site physiography
- Soil and geology
- Hydrogeology
- Meteorology
- Demography and population
- Land use
- Surface waters and water quality
- Floodplains
- Sensitive species

The level of detail warranted for each topic will vary from site to site and also depend on requirements of the lead regulatory agency.

5.3.1 Site Physiography

A discussion of the topography of the installation and the unit should be included. Topography is important since it may affect the feasibility of cleanup operations (e.g., access for and use of heavy equipment), as needed. In addition, topographic conditions may affect the potential for runoff and the migration of contaminants, if present, from the surface soil. Therefore, the need for runon/runoff controls should be evaluated when evaluating closure requirements and mitigation measures for site remediation/cap construction. Typically a topographic map showing a distance of 1,000 ft around the unit at a scale of 1 in. to not more than 200 ft should be provided.

5.3.2 Soil and Geology

Soil and geologic conditions are significant factors for evaluating the potential of soil contaminants, if present, to migrate to the groundwater.

Soil conditions should be discussed in terms of unconsolidated overburden as well as local soil deposits. Information needed to describe the geology of the bedrock includes bedrock type, lithology, petrology, structure, discontinuities, and unusual features such as igneous intrusive bodies (dikes), lava tubes, and solution cavities in limestone (karst). The type of information needed to characterize the geology of the unconsolidated overburden and soil deposits includes the thickness and areal extent of geologic units; lithology; mineralogy; and soil particle size, sorting, and porosity. Soil types and the depth range of each soil between the ground surface and the water table should also be addressed. Sources of geologic information include U.S. Geological Survey (USGS) topographic quadrangle maps, published reports (geologic reports, groundwater reports, soil survey reports), maps and files, state geological survey records, and local well drilling logs.

5.3.3 Hydrogeology

Hydrogeologic conditions at the unit are also important to evaluate the potential for contamination of groundwater and subsequent migration of contaminants in this medium. Geologic characteristics, hydraulic properties, and groundwater use at the region, installation, and unit should all be presented in the closure plan. The geologic characteristics discussion should include the type of water-bearing units and aquifer (overburden or bedrock), depths to the uppermost aquifer, description of the uppermost aquifer, and estimate of net recharge. The hydraulic properties information should include the hydraulic properties of the aquifer, pressure conditions, groundwater flow directions, rate, and discharge areas, as well as seasonal fluctuations of groundwater conditions. In assessing groundwater use, existing or potential aquifers should be identified and the use of groundwater determined.

Information concerning plumes of contamination (as appropriate) that have entered the groundwater from the OB/OD unit should be discussed.

General sources of regional hydrogeology information include the USGS, state geological surveys, local well drillers, and state and local water resource boards. Previous site-specific studies (i.e., Remedial Facility Investigation, etc.) may be available and useful to characterize site and unit hydrogeological conditions.

5.3.4 Meteorology

Meteorological and climatic information are generally only provided in closure plans as secondary background information. This is because the atmospheric pathway typically is not a significant exposure concern at an inactive OB/OD unit. However, for semi-arid and arid locations, wind erosion may be of potential concern if the surface soil is contaminated. Precipitation, temperature, wind speed, wind direction, and the presence of inversion layers, as well as mean values for evaporation, evapotranspiration, and estimated percolation, should be included. Information on weather extremes such as the occurrence of storms, floods, and heavy winds should also be provided. Typically, onsite meteorological data are not necessary to support closure decisions. Sources of atmospheric information frequently include the National Climate Center of the National Oceanic and Atmospheric Administration (NOAA) and state emergency planning offices.

5.3.5 Demography and Population

Demography and population should be addressed in general terms for both the installation and nearby population centers. This information is needed to qualitatively characterize the potential receptors in the general area in which the OB/OD is located. To present this information, a series of maps (i.e., unit, site, and regional), each of them identifying the location of the OB/OD unit, is recommended.

Census and other survey data may be used to identify and describe the population. Information may also be available from USGS maps, land use plans, zoning maps, and regional planning authorities.

5.3.6 Land Use

Current and future land use scenarios may need to be evaluated to support the determination of site-specific, risk-based cleanup levels and for remediation decisionmaking. The closure plan should identify the cantonment areas, testing areas, training areas, residential areas, and impact areas. Land use in nearby areas should also be identified as agricultural, residential, industrial, or other. The area should be classified as either urban or rural. It would be helpful to include a map that delineates the different uses. Sources for this information include zoning boards, the Census Bureau, regional planning agencies, and other local government entities.

5.3.7 Surface Waters and Water Quality

The potential impacts to surface waters and water quality from migration of potential contaminants from the OB/OD unit soil and/or groundwater may need to be evaluated on a site-specific basis. However, exposure scenarios for potential receptors at the OB/OD unit are more typically the limiting factor for risk-based cleanup levels. Therefore, the level of detail warranted for surface waters and water quality will depend on site-specific considerations.

The location and use of surface water at the installation and, if applicable, at, or in the vicinity of the OB/OD unit should be discussed. Surface waters that need to be identified include ditches, streams, ponds, and lakes. Surface water bodies can be classified into one of the following categories: streams and rivers; lakes and impoundments; wetlands and marine environments. Contaminant transport in surface water bodies is largely controlled by flow, which in streams is a function of the gradient, geometry, and coefficient of friction. Types of information that should be included, if available, are the physical dimensions, such as depth, area, and volume; residence time; and current direction and rates of the closest surface water body.

In addition, the water quality data for surface waters, especially any surface body close to the OB/OD unit, should be included in the closure plan as available. The type of parameters that should be considered include pH, temperature, total suspended solids, suspended sediment, salinity, and specific contaminant concentrations. Drinking water intakes and distribution systems should be discussed, and recreational (swimming, fishing) areas identified. Sources of information generally include local and state public agencies.

5.3.8 Floodplains

Floodplains, in particular flooding of the OB/OD unit, present special considerations for permitting and closure. Flooding of the OB/OD unit could result in the large-scale migration of contaminants, if present, to offsite receptors. Therefore, the approach to closure of an OB/OD unit that is located in a floodplain must be protective of human health and the environment, even during a flood. The Federal Emergency Management Agency (FEMA) has mapped much of the United States and is the best source of floodplain maps. For areas that have not been mapped by FEMA, hydrologic, geologic, and pedologic information identification of the 100-year floodplain can be obtained from the USACE, U.S. Soil Conservation Service, or the U.S. Geological Survey (USGS). In most cases, FEMA maps can be used to determine if the unit is within a 100-year floodplain.

5.3.9 Sensitive Species

The RCRA Subpart X closure performance standards require that closure ensure the protection of human health as well as the environment. Therefore, potential contaminants at OB/OD units as well as closure activities (e.g., soil removals, vegetation disturbances, etc.) may adversely impact sensitive species and should be addressed in the closure decisionmaking process.

The flora and fauna associated in and around the unit should be identified. Particular emphasis should be given to identification of sensitive environments, especially threatened and endangered species as well as their associated habitats. Species consumed by humans or part of the human food chain are also of great interest. Examples of sensitive environments include wildlife breeding areas, wildlife refuges, wetlands, and specially designated areas such as wild and scenic rivers or parks. Threatened and endangered species include both federally and state-listed species.

6. INVESTIGATIVE TECHNIQUES

A pre-closure site investigation of the OB/OD unit is needed to define the nature, magnitude, and spatial extent of OB/OD treatment residues. Verification (i.e., post-closure) sampling will also be needed after completion of clean closure. Post-closure groundwater monitoring will be required for closure as a landfill. This section discusses the technical aspects of designing and implementing site investigations to support OB/OD closures. However, site-specific requirements will vary on a case-by-case basis and should be negotiated with the lead regulatory agency.

The design of the site investigation for closure should consider the results of any previous studies (e.g., RFIs, RI/FSs, baseline sampling, routine monitoring, etc.). In addition, coordination of BRAC/IRP, RCRA, and CERCLA requirements/actions at the time of closure should be a major goal. The potential for site investigation cost avoidance from this coordination effort can be significant if investigation data can serve multiple needs.

Site investigation to support OB/OD closures should be based on the following (see Fig. 6-1):

- Sampling and analysis plan (SAP)
- Site-specific safety and health plan
- Selection of sample collection sites
- Monitoring well installation
- Sampling procedures
- Investigation-derived waste
- Target analytes
- Analytical methods

The SAP (which addresses all of the above) should be submitted as part of the closure/post-closure plan (or alternative enforceable closure document) if closure is imminent. If closure is not expected in the near future (e.g., a sampling plan for inclusion to an OB/OD permit application) a less detailed sampling plan with the emphasis on the overall goals and approaches for site characterization at the time of closure is recommended to ensure flexibility. (A closure plan amendment would, however, be needed with a detailed sampling plan when closure is imminent). Therefore, the closure plan requirements for the sampling plan should be discussed/negotiated with the lead regulatory agency. The investigation techniques selected should be based on applicable regulatory requirements and guidance as well as considering the applicability and usefulness of EM 200-1-3 as well as other USACE sampling and analysis guidance on a case by case basis (U.S. Army, September 1994).

Guidance on the conduct of site characterization screening assessments (i.e., baseline studies that are less comprehensive than a site investigation) to support operating permit versus unit closure decision making is provided in a companion guide (U.S. Army, January 1999).

Figure 6-1. Site investigation techniques to support OB/OD closures.

6.1 SAMPLING AND ANALYSIS PLAN

A site-specific SAP should be prepared to support the closure process. The USACE guidance (EM 200-1-3) as specified in Requirements for the Preparation of Sampling and Analysis Plans (U.S. Army, September 1994) may be useful for the preparation of a site-specific SAP. Certain situations may warrant or require that the SAP be written differently than the format described in the USACE guidance. The SAP guidance and SAP preparation guidance components are identified in Fig. 6-2.

The SAP should address the data quality objectives (DQOs) for the sampling and analysis program. DQOs are qualitative and quantitative statements that accomplish the following:

- Clarify the study objective;
- Define the most appropriate type of data to collect;
- Determine the most appropriate conditions from which to collect the data; and
- Specify tolerable limits on decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the decision.

The DQOs are then used to develop a scientific and resource-effective data collection and analysis design.

EPA has developed guidance for the DQO process as summarized below (USEPA, September 1994):

- Step 1: State the Problem – Concisely describe the problem to be studied. Review prior studies and existing information to gain a sufficient understanding to define the problem.

- Step 2: Identify the Decision – Identify what questions the study will attempt to resolve, and what actions may result.

- Step 3: Identify the Inputs to the Decision – Identify the information that needs to be obtained and the measurements that need to be taken to resolve the decision statement.

- Step 4: Define the Study Boundaries – Specify the time periods and spatial areas to which decisions will apply. Determine when and where data should be collected.

- Step 5: Develop a Decision Rule – Define the statistical parameter of interest, specify the action level, and integrate the previous DQO outputs into a single statement that describes the logical basis for choosing among alternative actions.

- Step 6: Specify Tolerable Limits on Decision Errors – Define the decision maker's tolerable decision error rates based on a consideration of the consequences of making an incorrect decision.

Figure 6-2. Sampling and analysis plan (SAP) guidance and preparation

- Step 7: Optimize the Design – Evaluate information from the previous steps and generate alternative data collection designs. Choose the most resource-effective design that meets all DQOs.

SAPs prepared in accordance with USACE SAP guidance are intended to be functionally equivalent to EPA SAPs, field sampling plans, and quality assurance (QA) project plans prepared under CERCLA and to data collection quality assurance plans and data management plans prepared under RCRA. To reflect current EPA guidance, the SAP should be divided into two parts if closure is imminent: a field sampling plan (FSP) and a quality assurance project plan (QAPP). However, if closure is not imminent (e.g., for closure plans included in OB/OD permit applications) the details needed for a QAPP would not be appropriate. The requirements for providing a QAPP with the closure plan should be discussed/negotiated with the lead regulatory agency.

The FSP should address the field activities, including all aspects of sampling and drilling. The QAPP, as needed, should address the DQOs, specific QA and quality control (QC) activities, and laboratory activities designed to achieve the data quality goals of the project.

The USACE guidance contains specifications for format and contents of the SAP and instructions for specifying and executing sampling, analysis, and related tasks for measurement of chemicals in the environment. An example comprehensive SAP outline is presented in Table 6-1. However, not all of the elements may be appropriate on a site-specific basis. Subjects not pertinent to a site should be identified in the SAP as not applicable.

Supplemental guidance applicable to OB/OD closures is provided in the subsections which follow in this closure/post-closure guidance document. Many states have their own requirements which may impact SAP preparation. The USACE SAP guidance complements existing USACE guidance as well as USACE guidance currently being developed.

Table 6-1. Sampling and Analysis Plan example outline (EM 200-1-3) (U.S. Army, September 1994)

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- Title Page
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Table 6-1. (Continued)

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Example List of Tables

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6.2 SITE-SPECIFIC SAFETY AND HEALTH PLAN

A site-specific safety and health plan (SSHP) should be prepared to supplement the SAP. The purpose of the SSHP is to outline health and safety procedures for site investigation, field activities, and onsite closure operations (see Fig. 6-3).

The SSHP must be administered by a qualified safety and health professional and should comply with all applicable Federal, state, and local health and safety requirements, including the Occupational Safety and Health Administration's (OSHA) requirements (29 CFR 1910 and 1926), specifically 29 CFR 1910.120, Hazardous Waste Operations and Response and EPA's Hazardous Waste Requirements (40 CFR 260-270). The latest edition of the U.S. Army Corps of Engineers Safety and Health Requirements Manual (EM 385-1-1) provides guidance for the preparation of SSHPs. However, compliance with EM 385-1-1 is not necessarily a prescribed requirement for all closure situations, and its applicability should be evaluated on a case-by-case basis. The applicability of Army Regulation 385-40, Supplement 1 to that regulation, and Ammunition and Explosives Safety Standards (AR 385-64) should also be evaluated on a site-specific basis. All field work should be performed in accordance with the accepted SSHP plan. The SSHP should follow the outline presented in Table 6-2. Subjects not pertinent to the SAP should be identified as not applicable.

Numerous potential hazards may be encountered when performing planned activities at OB/OD sites. Potential hazards at OB/OD sites can be segregated into two general categories, chemical hazards and physical hazards, as indicated below:

- Chemical hazards. The primary chemical hazard associated with investigations at OB/OD sites will be the potential for dermal contact with and inhalation of contaminants which may be present (especially associated with fugitive dust). A list of known/suspected contaminants should be included in the SSHP. Monitoring instrument action levels should be identified for each contaminant. Information concerning toxicity, and chemical and physical properties for the COCs, should be listed in a table.

- Physical hazards. Certain physical hazards may be encountered by field personnel engaged in onsite activities. Physical hazards that may be encountered during field activities at OB/OD sites include, but are not limited to:

  - Explosions and burns from UXO

  - Exposure to moving machinery such as drilling equipment

  - Military testing and training operations involving munitions and ordnance for OB/OD units located within active impact ranges

  - Uneven or unstable terrain (slip and trip hazards)

Figure 6-3. Site-specific safety and health plan (SSHP).

Table 6-2. Site-Specific Safety and Health Plan example outline

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	8.5	Decontamination Procedures
	8.6	Emergency Information
	8.7	Site Security
	8.8	Activity Hazard Analysis
	8.9	Site Inspection & Sampling

- Cuts and scrapes from shrapnel and sharp metal debris on and in the ground
- Strain sprains or muscle pulls
- Noise in excess of 85 decibels, A-weighted (dBA)
- Insect/snake bites
- Heat stress

A major hazard of concern at most OB/OD sites is the potential for UXO. Surface UXO can be detected visually and with magnetometer sweeps. However, subsurface UXO detection is a greater technical challenge and is a definite hazard for intrusive sampling.

The presence of UXO during OB/OD closure activities presents a hazard during the conduct of site investigations as well as during earth-moving operations. UXO detection and avoidance is the appropriate approach for site investigation field work. However, UXO disposal support by EOD staff may be needed to accomplish soil removal or for other closure activities involving heavy equipment.

Standard UXO detection techniques applicable to site investigation support include the following:

- Surface magnetometer sweeps along with visual observations
- Use of down-hole magnetometers for drilling and excavation operations
- Use of geophysical surveys to identify subsurface anomalies which may be due to UXO

The effective depth range of magnetometers for small UXO items (i.e., 20 mm projectiles and grenades, etc.) is about 2 ft. Geophysical surveys (e.g., use of electromagnetic techniques) can be used to identify potential subsurface UXO at greater depths. However, the use of electromagnetic induction equipment must be evaluated on a site-specific basis to ensure that the frequency range is deemed intrinsically safe with respect to the potential detonation of UXO. This can be accomplished by obtaining a Hazards of Electromagnetic Radiation to Ordnance (HERO) certification from the Naval Surface Warfare Center for each specific instrument on a site-specific basis.

The USACE and the SERDP continue to evaluate current and evolving technologies for the conduct of UXO detection surveys.

UXO avoidance typically involves the following approaches:

- Mapping/flagging detected UXO
- Abandoning borings/excavations with known UXO
- Identifying safe work zones and access corridors

Specific details regarding safety procedures for UXO detection, avoidance, and disposal should be obtained from the latest edition of the following documents:

- Generic Scope of Work for Ordnance Avoidance Operations (U.S. Army, April 1996)

- Safety Concepts and Basic Considerations for Unexploded Ordnance (UXO) Operations (U.S. Army, February 1996)

- Explosive Ordnance Reconnaissance, FM 9-16 (U.S. Army, July 1981)

- Explosive Ordnance Disposal Service and Unit Operations, FM 9-15 (U.S. Army, April 1993)

A copy of each of the first two documents (which represents USACE guidance issued by the U.S. Army Engineering Support Center, Huntsville, Alabama) is provided in Appendix H.

6.3 SELECTION OF SAMPLE COLLECTION SITES

Selection of sample collection sites and environmental media at OB/OD sites is dependent on many factors and initially requires obtaining site-specific information for proper design of a sample strategy. Site-specific data include background information regarding OB/OD treatment and site physical characteristics such as the following.

- Background information includes compiling a list of the types and quantities of wastes treated, the treatment methods, knowledge of OB/OD management practices, and obtaining any previous environmental studies and analytical results.

- Site physical characteristics include geographic location, site topography, size of OD area, soil type and soil permeabilities, precipitation data, depth to groundwater in the uppermost aquifer, drainage patterns, nearest surface water body, and prevailing wind direction.

The above information should be described in the SAP and should be considered during the selection of sample collection sites. Frequently this information will be available from previous studies (e.g., an RFI, RI/FS, or baseline environmental sampling program).

Several methods can be used in selecting sampling locations. Selection of a particular method is dependent on knowledge of the release at the OB/OD site. Judgmental sampling involves the selection of sample locations based on existing knowledge of release (e.g., visual evidence such as stained or discolored soil or geophysical data). This method will generally bias the results toward higher contaminant concentrations. Systematic sampling, on the other hand, involves collecting samples from an established grid. This can help determine the boundaries of a contaminated area and can be used when there is limited or no knowledge of release. Usually a combination of both judgmental and systematic sampling strategies provides an effective sampling approach at OB/OD sites.

EPA guidance regarding the selection of sampling locations is provided in the following documents:

- 40 CFR 264, Subpart F Ground-Water Monitoring (permitted status)

- 40 CFR 265, Subpart F Ground-Water Monitoring (interim status)

- <u>Test Methods for Evaluating Solid Waste</u>, SW-846 (USEPA, 1995c)

- <u>Interim Final RCRA Facility Investigation Guidance</u> (USEPA, May 1989b)

- <u>Soil Screening Guidance: User's Guide</u> (USEPA, April 1996)

- <u>RCRA Ground-Water Monitoring: Draft Technical Guidance</u> (USEPA, November 1992)

The latest versions of these guidance documents should be considered, as appropriate, to design the sampling network for each of the media (see Fig. 6-4). Site-specific sampling location requirements should be based on consultations and negotiations with the lead regulatory agency. There appears to be a great variability between regulatory agencies in the positions on this issue, and many regulatory agencies do not accept the use of composite samples.

6.3.1 Surface Soil Sampling Locations

The selection of surface soil sampling locations involves the following steps as indicated in Fig. 6-5:

- Conduct evaluation of soil sampling results from previous site studies and Army OB/OD field studies as well as the application of soil screening guidance developed by EPA.
- Identify OB/OD contamination areas.
- Select appropriate exposure areas based on future land use.
- Determine the number of samples needed.

A strategy for the collection of surface soil samples has been included in the Soil Screening Guidance: User's Guide (see Appendix G) (USEPA, July 1996). Pursuant to this guidance the study area can be stratified into the following contamination areas based on previous site-specific studies and/or knowledge of OB/OD impacts (as discussed in Sect. 3):

- Area of known contamination (i.e., the source area as applied to OB/OD sites)
- Area of potential contamination (i.e., the impact area as applied to OB/OD sites)
- Area that may be contaminated and cannot be ruled out (i.e., the fragmentation area as applied to OB/OD sites)
- Background area (i.e., not impacted by OB/OD operations).

A summary of these contamination areas is presented in Table 6-3.

The source area for OB should be defined as the burn pan area plus an additional 1 m border zone (since the potential for spillage of energetics, residues, and ashes is greatest at the edge of the burn pans). The detonation pits/craters should be considered as the source area for OD.

Fig. 6-5. Selection of surface soil sampling locations-overview.

Table 6-3. Example of contamination areas for OB/OD units

Treatment mode	Source area	Impact area	Fragmentation area	Background area
OB	Burn (pan) area and 1 m border zone beyond	10-20 m radius from burn point[a]	Based on maximum treatment quantity per pan[b]	Upwind of fragmentation zone
OD	Pit/crater areas	60 m radius from detonation point[c]	Based on maximum treatment quantity per pit[d]	Upwind of fragmentation zone

[a]Based on information presented in Sect. 3.

[b]May not be applicable if only bulk propellants treated (i.e., no munitions or bulk explosives such as TNT).

[c]Based on 2,000 lb NEW detonation. Should be adjusted for site-specific treatment quantities as needed. Area of disturbed soil may be an indication of the impact zone.

[d]Consideration should be given for the reduction of fragmentation distances for subsurface detonations.

The impact area for OB should be limited to within 10-20 m of the treatment point associated with "kickouts." A 200 m impact area radius for a 2,000 lb NEW detonation may be considered to account for the major area for impacts associated with ejecta and fallout materials for OD. These criteria have been based on OB/OD field tests conducted at the DPG, Utah (as discussed in Sect. 3). Site-specific information should be used as available to define the OB/OD impact areas. For example, the area of disturbed surface soils may be an indication of the actual impact area.

The OB/OD fragmentation area corresponds to the fragmentation distances presented in Sect. 3. However, as appropriate, consideration should be given for the reduction in fragmentation distances for subsurface detonations. Also, these fragmentation distances may not be applicable for OB if only bulk propellants were treated (i.e., no munitions or bulk explosives such as TNT). While the potential for shrapnel exists in the fragmentation area, the potential for soil contamination is considered minimal.

The background area should be selected to represent soil conditions in the vicinity of the OB/OD unit but outside the zone of influence of the unit. This can generally be accomplished by selection of a background area outside the fragmentation area, beyond the OB/OD unit boundary, and upwind (based on the prevailing wind direction) of the unit. This background area should be representative of local land use and not necessarily pristine conditions. For example, OB/OD units located within military ranges will be associated with background contamination levels.

An illustration of the application of these contamination areas to an example OB/OD unit is presented in Fig. 6-6. This example is based on fixed locations for OB burn pans and OD pits. The situation is much more complicated if the burn and detonation locations were routinely moved. For situations where the burn and detonation locations were variable, "an active area" should be determined.

The active area is defined as the primary area within which OB/OD activities have occurred. Thus, the active area can be considered to be equivalent to a combined source/impact area. This active area can be identified based on installation staff historical knowledge, OB/OD records and the evaluation of historical aerial photographs. In addition, geographical techniques may be useful (e.g., use of electromagnetic induction to identify soil conductivity anomalies which may represent disturbed subsurface soil due to OD operations).

EPA recommends dividing the source and impacts areas into exposure areas (EAs) commensurate with land use. The Soil Screening Guidance uses an example EA of 0.5 acre for future residential use. Default exposure areas for other land use scenarios are provided in Table 6-4 as default values. However, subdivision plans for the OB/OD unit may warrant the use of site-specific values.

Fig. 6-6. Example of OB/OD contamination areas.

Table 6-4. Default exposure areas as a function of future land use

Future land use[a]	Typical exposure area (acres)[b]
Residential	0.5
Commercial	1
Agricultural	10
Military ranges	Site specific
Recreational	Site specific

[a]Pursuant to the "Draft EPA Clean Closure Guidance," clean closures must be based on residential land use exposure assumptions. (USEPA, 1997a).

[b]Site-specific exposure areas should be used as available based on more detailed knowledge of future land use and expected subdivision of the OB/OD unit.

Note: The background EA should be considered to be the same as the future land use EA.

The default number of samples recommended by EPA for each EA is six composite samples pursuant to the Soil Screening Guidance. Each composite sample typically consists of four random individual samples. This is accomplished by dividing each EA into four subareas as illustrated in Fig. 6-7. However, the number of composite surface soil samples and specimens per composite should be selected to be statistically significant considering the Soil Screening Guidance and site-specific data quality objectives. Guidance for the selection of sample size is also presented in this figure. In its Soil Screening Guidance, EPA provides the following rationale for the case of composite surface soil samples:

> As explained in the Supplemental Guidance to RAGS: Calculating the Concentration Term (USEPA, 1992), an individual is assumed to move randomly across an EA over time, spending equivalent amounts of time in each location. Thus, the concentration contacted over time is best represented by the spatially averaged concentration over the EA. Ideally, the surface soil sampling strategy would determine the true population mean of contaminant concentrations in an EA. Because determination of the "true" mean would require extensive sampling at high costs, the maximum contaminant concentration from composite samples is used as a conservative estimate of the mean.
>
> Composite surface soil samples. Because the objective of surface soil screening is to estimate the mean contaminant concentration, the physical "averaging" that occurs during compositing is consistent with the intended use of the data. Compositing allows sampling of a larger number of locations while controlling analytical costs, since several individual samples are physically mixed (homogenized) and one or more subsamples are drawn from the mixture and submitted for analysis.

Example guidance for the selection of the number of composite samples for OB/OD sites is provided in Table 6-5. The number of composite samples selected as well as the number of discrete samples per composite should be based on data quality objectives (e.g., the probability of decision error) as well as the expected coefficient of variation for the samples. Previous sampling data should be used or limited preliminary sampling data should be obtained to determine a site-specific coefficient of variation. Six composite samples are typically used (assuming a coefficient of variation of 2.5) to evaluate each EA for the impact area (as previously discussed). These samples should exclude the source area(s). The background area (as represented by one EA) is also characterized by the evaluation of six composite samples.

Discrete surface soil samples (even those used to obtain a composite sample) should be collected using a small area (i.e., within a 4-ft diameter) composite sampling pattern as illustrated in Fig. 6-8. This is based on surface soil sampling tests for energetics conduced by the U.S. Army at several OB/OD units and military ranges (U.S. Army, December 1999). These tests indicated a very heterogeneous distribution of energetics within surface soils and that use of the sample collection strategy as illustrated in Fig. 6-8 provided more reliable site characterization data.

Fig. 6-7. Application of EPA Soil Screening Guidance (USEPA, April 1996).

Table 6-5. Example of the number of composite surface soil samples for each contamination area based on a coefficient of variation of 2.5 and EPA Soil Screening Guidance (USEPA, July 1996)

Contamination area	Number of surface soil composite samples[a]
Source	1 composite per OB pan or OD pit or 6 composite samples total (whichever is greater)
Impact	6 composites per EA
Fragmentation	6 composites for the entire area
Background	6 composites for one EA

[a]Each composite sample typically consists of four random individual samples.

[b]Some regulatory agencies may require the use of discrete samples (instead of composite samples).

Fig. 6-8. Composite sampling pattern at each surface soil sampling location

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Individual source areas (i.e., OB burn areas and OD pits/craters) will generally be much smaller than the EA. Thus, the collection of just one composite sample per individual source area is appropriate. But additional samples are needed for statistical analyses. Therefore, the consolidated source area(s) should be evaluated through the collection of one composite sample for each individual source area (i.e., burn area or pit/crater) or a total of six composite samples, whichever is greater.

The fragmentation areas also warrant special consideration regarding sample size. As previously discussed, the potential for soil contamination in this area is considered minimal. Therefore, a less comprehensive sampling approach than used for the source and impact zones is appropriate. A screening approach using a total of six composite samples should be considered to evaluate the potential for surface soil contamination within the fragmentation area (outside of the source and impact areas). If screening results indicate contamination at levels of concern, a more comprehensive sampling program may be needed. A potential approach for these cases is to apply a standard EA grid over the fragmentation area. Each EA adjacent to the impact area should be evaluated. Adjacent EAs at increasing distances should subsequently be evaluated in progression until soil concentrations are acceptable.

EPA Soil Screening Guidance includes the following recommendations regarding soil sampling depths:

> The depth over which surface soils are sampled should reflect the type of exposures expected at the site. The Urban Soil Lead Abatement Demonstration Project (USEPA, 1993d) defined the top 2 centimeters as the depth of soil where direct contact predominantly occurs. The decision to sample soils below 2 centimeters depends on the likelihood of deeper soils being disturbed and brought to the surface (e.g., from gardening, landscaping or construction activities).

Regulatory agencies have considered the surface soil zone to be within the 0 to 6 in. depth interval. For certain cases where OB/OD soils have been subject to routine tilling as a fire control method, a surface soil sampling depth of 0 to 1 ft may be appropriate. Thus, the lead regulatory agency should be consulted in order to ascertain its position on this issue. Sampling depths of greater than 6 in. are considered subsurface samples in this Army closure guidance document.

Alternatives to application of the EPA Soil Screening Guidance may need to be considered based on the requirements of the lead regulatory agency, as previously indicated. For example, Indiana guidance states that a maximum sampling grid interval of 10 ft be used for most sites (IDEM, March 1994). The number of actual sampling locations is based on the cubic root of the total number of grid intersection points (with a minimum of three required). Sampling locations are selected at random.

Another example approach to the selection of sampling locations is provided in guidance developed by Michigan (MDNR, April 1994). Sampling grid interval ranges are 15 to 50 ft for site areas of 0.25 acre up to 3.00 acres and 30 ft and greater for areas of greater than or equal to 3.00 acres. Sampling locations may include all of the grid points or a phased subset (e.g., based on random selection). A minimum of 12 samples or 25 percent of the grid points, whichever is larger, of the total grid stations should be sampled and analyzed initially. Additional samples may be needed if statistical analysis of the initial data indicates the need for more samples.

In one OB clean closure case, EPA Region 5 has recommended use of a modified Michigan grid interval approach (which in this case was a grid interval of 50 ft) for prior treatment areas (i.e., impacted by spillage and kickouts). However, a grid interval of 100 ft has been considered appropriate for the remainder of the OB unit where atmospheric deposition was the major basis for potential soil contamination. For this case EPA Region 5 considers that surface soil sampling for each grid point is needed but limits the target analytes to the primary contaminants of concern (i.e., metals and energetics).

The Indiana and Michigan guidance examples represent a very comprehensive approach for the selection of sampling locations and an alternative to the composite sampling approach. Such an approach may not be required or warranted for many OB/OD units. The selection of a grid sample interval may also be dependent on the approach used for analysis of spatial variations of analytical results. For example, the use of geostatistical approaches such as kriging methods may provide a basis for scaling down the sampling grid interval in some situations (ASTM, 1996a; ASTM, 1996b; ASTM, 1996c). These examples are provided to demonstrate the variability of approaches which may be selected for a site-specific application, and not as specific recommendations.

6.3.2 Subsurface Soil Sampling Locations

Subsurface soil sampling program design includes the following:

- Selection of the number of samples
- Identification of the type of samples (i.e., random or biased)
- Specification of sampling layer increments
- Determination of the maximum sampling depth.

This process is depicted in Fig. 6-9.

Subsurface soil sampling is primarily limited to the source area. The subsurface variability of contaminant concentrations is generally not as great as for the surface soils. Therefore, the EPA Soil Screening Guidance recommends taking 2-3 individual soil borings located in areas suspected of having the highest contaminant concentrations within the source. Application of this guidance to OB/OD units is summarized in Table 6-6.

Fig. 6-9 Selection of subsurface sampling locations based on EPA Soil Screening Guidance (U.S. EPA, April 1996) - overview.

Table 6-6. Example of the number of individual subsurface soil samples for each contamination area based on USEPA Soil Screening Guidance (USEPA, July 1996)

Contamination area	Number of individual samples	Sample type	Sampling interval	Sampling depth
Source				
• OB burn area	2-3	Biased	0.5 ft	2 ft min.[a]
• OD pit/crater	2-3	Biased	2.0 ft	Potential crater depth plus 2.0 ft min.[a]
Impact	None[b]	NA	NA	NA
Fragmentation	None[b]	NA	NA	NA
Background				
• OB	1[c]	Random	Duplicate OB source	Duplicate OB source
• OD	1[c]	Random	Duplicate OD source	Duplicate OD source

[a]Sampling should continue for increasing depths, as needed, until contamination levels are acceptable. However, greater sampling intervals may be warranted for those cases.

[b]Should be evaluated on a site-specific basis.

[c]Background OB and OD boring can be collocated.

The recommended number of subsurface samples per OB burn area or OD pit/crater is 2-3, considering the EPA Soil Screening Guidance. The locations of the borings should be selected on a biased basis to depict maximum subsurface contamination. For OB source areas, the subsurface samples should be taken at 0.5 ft intervals to a minimum depth of 2.0 ft. Subsurface samples should be collected at 2.0 ft intervals for OD source areas to a minimum depth equivalent to the pit/crater depth plus 2.0 ft. In both cases, sampling should continue to greater depths until soil contamination concentrations are acceptable.

Subsurface background samples from one boring should be obtained. The location of the boring within the background area should be selected on a random basis. The sampling intervals and depth should duplicate the deepest OB source boring and deepest OD source boring.

Typically subsurface samples are not warranted for the impact and fragmentation areas (because of the expected low levels of surface contamination). However, the need for subsurface samples in the areas should be evaluated on a site-specific basis.

The Indiana and Michigan guidance again provides examples of alternative approaches to the EPA Soil Screening Guidance (IDEM, March 1994; MDNR, April 1994; USEPA, April 1996). Both Indiana and Michigan recommend that subsurface samples be taken at each surface sampling location. Indiana guidance indicates that subsurface samples should be obtained as follows:

- Every 6 in. to a depth of 2 ft
- Every 1 ft from 2 to 5 ft
- Beyond the 5 ft depth (as needed based on site-specific conditions) at 2 to 5 ft intervals

The Indiana guidance represents a very comprehensive approach for subsurface soil sampling. Such an approach may not be required or warranted based on site-specific requirements.

In one OB clean closure case, EPA Region 5 has recommended that, because of the limited depth of contamination expected for OB, only surface soils be collected for pre-closure sampling. However, sidewall and subsurface verification soil samples would be needed at a particular location if soil excavation is required.

6.3.3 Sediment Sampling Locations

The program design for sediment sampling is provided in Fig. 6-10. Sediment sampling will only be needed to support risk-based closures at OB/OD sites where the overland runoff pathway is of concern. This pathway is of particular concern if the intent is to support the rationale for no cleanup action. Previous site-specific studies and results from surface soil sampling can be used for sediment sampling decision making.

Fig. 6-10. Selection of sediment sampling locations - overview.

Recommendations for sediment sampling are presented in Table 6-7. This approach is based on EPA's RFI Guidance and its Soil Screening Guidance (USEPA, May 1989b; USEPA, April 1996). The RFI guidance recommends sampling (contamination) areas which correspond to the following:

- Background (i.e., upgradient of the OB/OD unit beyond the fragmentation area)
- Drainage path (i.e., downgradient of the OB/OD unit, preferably beyond the fragmentation area).
- Receiving surface water (i.e., the nearest major surface waste feature).

A minimum of four discrete sediment soil samples should be obtained to ensure statistical significance for each contamination area as defined above. The sampling interval/maximum depth is 2 cm. The selection of soil sampling locations may be made on a random or grid basis.

Table 6-7. Example of the number of sediment samples

Contamination area	Minimum number of discrete samples[a]	Sampling interval/depth
Background (upgradient of OB/OD)	4	2 cm
Drainage path (downgradient of OB/OD)	4	2 cm
Receiving surface water (downgradient of drainage path)	4	2 cm

[a]Minimum of 4 individual samples needed for statistical significance.

6.3.4 Surface Water Sampling Locations

The program design for surface water sampling (see Fig. 6-11) is based on the approach for sediment sampling. Surface water sampling will only be needed to support risk-based closure of OB/OD sites where the overland runoff pathway is of concern and there is a nearby receiving water body. This pathway is of particular concern if the intent is to support the rationale for no cleanup action.

Table 6-8 summarizes the typical number of surface water samples needed based on the sediment sampling strategy. The number of sampling locations and depth intervals, however, should be evaluated considering site-specific hydrogeological conditions and sampling access limitations.

Fig. 6-11. Selection of surface water sampling locations-overview.

Table 6-8. Example of the number of surface water samples

Contamination area	Number of composite samples[a]	Sampling depths
Background (upstream of OB/OD)	6	Site specific
Drainage path (downstream of OB/OD)	6	Site specific
Receiving surface water (downstream of drainage path)	6	Site specific

[a]Each composite sample consists of 4 individual random samples.

6.3.5 Groundwater Monitoring Locations

The need for a groundwater monitoring program should be negotiated with the lead regulatory agency on a case-by-case basis. Small OB/OD units, units that do not have significant soil contamination, arid or semi-arid locations as well as low soil permeability conditions are examples which may not warrant the conduct of groundwater sampling or monitoring.

The development of a groundwater monitoring strategy to support OB/OD closures should address the following factors (see Fig. 6-12):

- Characterize site hydrogeology.
- Evaluate groundwater monitoring exemption criteria
- Design groundwater monitoring well network.
- Evaluate groundwater monitoring in aquifers dominated by conduit flow.

The need for site hydrogeologic and groundwater monitoring data, however, should be limited to the uppermost aquifer.

The site-specific groundwater monitoring program should be based on previous site studies (as available), EPA guidance, and EPA regulations. Previous site studies may have resulted in the installation of monitoring wells. Therefore, available groundwater data should be evaluated and the lead regulatory agency consulted to determine if additional wells or sampling are warranted to support closure. States may also have requirements which must be addressed. Therefore, groundwater site hydrogeological and groundwater monitoring requirements for closure may vary significantly depending on the requirements and policy of the lead regulatory agency. Also, UXO safety hazards and in certain cases climate (e.g., high water levels in locations such as Florida, and cold climates) may limit the installation of groundwater wells. Under some conditions, direct-push techniques may be all that is needed to determine if contaminants exist in the groundwater. Therefore, the application of direct-push techniques should be considered on a case-by-case basis as a cost-effective alternative to the installation of

Fig. 6-12. Selection of groundwater monitoring locations - overview.

groundwater monitoring wells. However, installation-specific groundwater monitoring requirements should be based on regulatory negotiations. If wells are required, their purpose may or may not be long-term monitoring, depending on the analytical results and regulatory requirements.

The purpose of the following subsections is to discuss the technical approach for the conduct of a groundwater monitoring program, if required.

6.3.5.1 Characterizing Site Hydrogeology

The hydrogeologic conditions for the uppermost aquifer at the OB/OD unit should be characterized as input to the design of a groundwater monitoring system. Available information about the hydrogeology of the site and OB/OD unit should be reviewed to gain an understanding of the stratigraphic distribution of soil, unconsolidated materials, and rock of the surface and groundwater. Typically, information will be available from RFI, RI/FS studies, or baseline environmental monitoring at the OB/OD unit.

Information needed to characterize the hydrogeology of the OB/OD unit may include the following:

- Geological data
    - The lateral and vertical extent of the uppermost aquifer;
    - The lateral and vertical extents of upper and lower confining units/layers;
    - The geology at the owner/operator's facility (e.g., stratigraphy, lithology, structural setting); and
    - The chemical properties of the uppermost aquifer and its confining layers relative to local groundwater chemistry and hazardous wastes managed at the facility, as it relates to the parameters specific in 40 CFR Part 265.
- Groundwater flow of the uppermost aquifer and its confining layer(s) at the unit:
    - The vertical and horizontal directions of groundwater flow in the uppermost aquifer;
    - The vertical and horizontal components of hydraulic gradient in the uppermost aquifer;
    - The hydraulic conductivities of the materials that comprise the uppermost aquifer and its confining units/layers;

- The average linear horizontal velocity of groundwater flow in the uppermost aquifer; and

- Seasonal/temporal, natural, and artificially induced (e.g., offsite production well pumping, agricultural use) short-term and long-term variations in groundwater elevations and flow patterns.

Supplemental hydrogeological data may need to be obtained if available information is not sufficient. At a minimum, direct methods should be used for determining site hydrogeology (e.g., subsurface borings, water level elevation measurement, textural analysis of soil samples). Indirect methods, especially geophysical methods (e.g., resistivity and seismic surveys), may provide valuable information for planning direct field measurements. Information obtained by indirect methods also can be used in conjunction with information obtained by direct techniques to interpolate geologic data between points where direct measurements are made. Information gathered by indirect methods alone, however, will not provide the detailed information necessary for complete characterization of a site. Conclusions drawn from indirect site investigation methods (e.g., geophysical surveys, aerial photographs) should be confirmed by, and correlated with, direct measurements.

Additional guidance on characterizing site hydrogeology is presented in RCRA Ground-Water Monitoring: Draft Technical Guidance (USEPA, November 1992).

6.3.5.2 Groundwater Monitoring Exemption Criteria

Groundwater monitoring may not be appropriate for many OB/OD sites for pre-closure site investigations or post-closure monitoring (for closure as a landfill), especially those located in remote, arid, or semiarid areas of the West. Also, groundwater sampling/ monitoring may not be warranted for small OB/OD units and others that do not have significant soil contamination. In addition, available groundwater monitoring data may be sufficient to support clean closure. However, routine monitoring will be required for closure as a landfill and other "dirty" closures.

Previous Army OB/OD site studies (discussed in Sect. 3) have concluded that the potential for groundwater contamination is insignificant for sites which meet one of the following criteria:

- Excess evaporation (compared to precipitation) exceeds 2 ft per year and no free liquids were used for treatment, or

- The OB/OD unit is underlain by a thick sequence of unsaturated clayey soils of low permeability (less than 1 E-04 cm/sec).

The following factors must be addressed for consideration for an exemption from groundwater monitoring requirements pursuant to 40 CFR 265, Subpart F (Groundwater Protection Standard):

- Potential adverse effects on groundwater quality, considering:
    - The physical and chemical characteristics of the waste in the regulated unit, including its potential for migration;
    - The hydrogeological characteristics of the facility and surrounding land;
    - The quantity of groundwater and the direction of groundwater flow;
    - The proximity and withdrawal rates of groundwater users;
    - The current and future uses of groundwater in the area;
    - The existing quality of groundwater, including other sources of contamination and their cumulative impact on the groundwater quality;
    - The potential for health risks caused by human exposure to waste constituents;
    - The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents; and
    - The persistence and permanence of the potential adverse effects.
- Potential adverse effects on hydraulically connected surface water quality, considering:
    - The volume and physical and chemical characteristics of the waste in the regulated unit;
    - The hydrogeological characteristics of the facility and surrounding land;
    - The quantity and quality of groundwater, and the direction of groundwater flow;
    - The patterns of rainfall in the region;
    - The proximity of the regulated unit to surface waters;
    - The current and future uses of surface waters in the area and any water quality standards established for those surface waters;

- The existing quality of surface water, including other sources of contamination and the cumulative impact on surface-water quality;

- The potential for health risks caused by human exposure to waste constituents;

- The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents; and

- The persistence and permanence of the potential adverse effects.

Thus, each of these factors should be addressed in order to justify an exemption from groundwater monitoring. In addition to 40 CFR requirements, there may be Federal and state Applicable or Relevant and Appropriate Requirements (ARARs) that need to be considered as well.

6.3.5.3 Groundwater Monitoring Well Network

Standard RCRA protocol is to locate one groundwater monitoring well upgradient (to characterize background) and three, at a minimum, wells downgradient at the point of compliance (i.e., the unit boundary). The downgradient well locations should be selected to intercept potential pathways for contaminant migration. A typical groundwater detection monitoring well network design is illustrated in Fig. 6-13.

Multiple monitoring wells (well clusters or multilevel sampling devices) should be installed at a single location when: (1) a single well cannot adequately intercept and monitor the vertical extent of a potential pathway of contaminant migration, or (2) there is more than one potential pathway of contaminant migration in the subsurface at a single location, or (3) there is a thick saturated zone and immiscible contaminants are present, or are determined to potentially occur after considering waste types managed at the facility. Conversely, at sites where groundwater is contaminated by a single contaminant, where there is a thin saturated zone, and where the site is hydrogeologically homogeneous, the need for multiple wells at each sampling locations is reduced. The number of wells that should be installed at each sampling location increases with site complexity.

6.3.5.4 Groundwater Monitoring for Aquifers Dominated by Conduit Flow

For aquifers dominated by conduit flow, subsurface conduits are the primary pathways that contaminant releases follow. Identifying and intercepting these conduits with wells constitute an extremely formidable task. Identifying contaminant transport pathways requires detailed site characterization beyond that currently being performed at most RCRA facilities. In addition, the wide fluctuations in the water table that are characteristic of aquifers dominated by conduit flow make identification and satisfactory monitoring of the uppermost aquifer particularly difficult.

Fig. 6-13. Typical detection groundwater monitoring well network design

It may be possible for some facilities that are sited above conduit flow aquifers (e.g., karst geology) to utilize groundwater monitoring wells. However, it may be necessary to monitor seeps, springs, and caves that are hydraulically connected to the uppermost aquifer and that are within the facility boundary to supplement the monitoring well network. These supplemental monitoring sites can be used in conjunction with point-of-compliance wells to detect releases from the OB/OD unit. The following alternative groundwater monitoring strategies should be considered for OB/OD sites located above aquifers dominated by conduit flow:

- Fracture trace analyses
- Tracing to identify monitoring sites
- Use of springs as monitoring sites

These approaches need to be evaluated on a site-specific basis. Additional guidance is provided in RCRA Ground-Water Monitoring: Draft Technical Guidance (USEPA, November 1992).

6.3.6 Air Monitoring

Air monitoring is not expected to be needed to support OB/OD closure decisionmaking or for post-closure monitoring. The primary air pathway for inactive or closed OB/OD units is via wind erosion of contaminated soils. These wind erosion events are episodic in nature, and a long-term air monitoring program would be needed to characterize impacts. However, standard modeling approaches (which utilize soil sampling results as input) are available to more cost-effectively evaluate potential wind erosion impacts. Methods for modeling wind erosion are discussed in Sect. 8.

The greatest risk associated with air pathway exposures at closure of OB/OD units is to onsite remediation workers. Appropriate wet methods of fugitive dust control during remediation and personal breathing zone monitoring may be appropriate occupational health measures to consider on a site-specific basis.

6.4 MONITORING WELL INSTALLATION

Guidance for the installation of monitoring wells is presented in RCRA Ground-Water Monitoring: Draft Technical Guidance (USEPA, November 1992). Following is a summary of the EPA guidance regarding the following monitoring well subjects (see Fig. 6-14):

- Monitoring of well drilling methods
- Decontamination of drilling equipment
- Well diameter
- Stratigraphic control
- Well casing and screen materials
- Well intake design
- Annular sealants
- Surface completion
- Well surveying
- Well development
- Documentation of well design, construction and development
- Specialized well design

The EPA guidance should be consulted for additional details. Some states may have specific guidance/regulations for monitoring well installation that are more stringent than the EPA guidance.

6.4.1 Monitoring Well Drilling Methods

Alternative drilling methods for various geologic settings are summarized in Table 6-9. The access and work areas for the drilling operations should be subject to a surface magnetometer sweep to detect and avoid UXO. Geophysical techniques should also be considered if subsurface UXO is a concern.

The geophysical results should be used to avoid drilling in locations associated with potential UXO. Nondetection results from a geophysical survey should not be considered a positive indication that the subsurface is UXO-free. In all cases the drilling operations should be limited to 2 ft depth intervals followed by a down-borehole magnetometer check for UXO. This procedure should be repeated to the maximum depth of the auger, but not less than 6 ft. Magnetometer surveys should be continued at 2 ft intervals until virgin soil is encountered. This approach requires frequent repositioning of the drill rig (which presents a safety hazard which should also be addressed in the SAP). If UXO is detected, the borehole should be checked by a UXO specialist to determine if UXO disposal is needed. The UXO borehole should be filled if abandoned. An alternative drilling location should then be selected. Consult Appendix H for additional UXO avoidance procedures.

Fig. 6-14. Preparation of groundwater monitoring well specifications.

Table 6-9. Drilling methods for various geologic settings

Geologic setting	Drilling methods							
	Air rotary[a,b,c]	Water/ mud rotary[a]	Cable tool	Hollow-stem continuous auger[b]	Solid-stem continuous auger[d]	Jet percussion[b]	Dual-wall reverse circulation	Driven wells[b]
Unconsolidated or poorly consolidated materials less than 125 ft deep	•	•	•	•	•	•	•	•
Unconsolidated or poorly consolidated materials more than 125 ft deep	•	•	•				•	
Consolidated rock formations less than 500 ft deep	•	•	•				•	
Consolidated rock formations more than 500 ft deep	•	•	•				•	

[a]Includes conventional and wireline core drilling.

[b]Not recommended for the installation of groundwater monitoring wells.

[c]Not desirable for detailed subsurface characterization and in areas where volatile organic compound (VOC) contamination is suspected.

[d]Above any saturated zones.

Note: Although several methods are suggested as appropriate for similar conditions, one method may be more suitable than the others. This determination is based on site-specific conditions and the judgment of the geologist and the driller.

Source: USEPA, November 1992.

In some cases the use of remotely operated drill rigs may be warranted at high-risk UXO sites. The U.S. Army Center for Health Promotion and Preventive Measures has developed a remote-controlled drill rig which has been used for OB/OD site investigations. Remote-controlled drilling rigs may also be available from the Corps of Engineers Districts and the private sector. However, UXO surveys and down-borehole UXO detection checks are still recommended to reduce hazards to the field crew and the drilling equipment.

6.4.2 Decontamination of Drilling Equipment

All drilling equipment that will encounter formation materials (e.g., augers, samplers, tremie pipes) should at a minimum be decontaminated between boreholes and, in the case of samplers, between samples. When cross-contamination between zones within a single borehole is a concern, equipment should be decontaminated more frequently. The general cleaning procedure for drilling equipment should include washing the equipment with potable water and/or hot pressurized potable water. For more contaminated equipment, this procedure should be followed by a wash with nonphosphate detergent and a final rinse with potable water.

6.4.3 Well Diameter

To avoid the possibility of having to handle large amounts of purged contaminated water, EPA recommends the use of either 2-in. or 4-in. diameter wells. The use of larger diameter wells may be necessary where dedicated purging or sampling equipment is used or where the well is screened in a deep formation.

6.4.4 Stratigraphic Control

Adequate stratigraphic control is critical to the proper vertical placement of well screens. Samples should be collected from boreholes at all suspected changes in lithology. The deepest borehole drilled at the site should be continuously sampled. For boreholes that will be completed as monitoring wells, at least one sample should be collected from the interval that will be the monitoring well intake interval (i.e., screened interval or open, uncased interval). EPA recommends that all boreholes be continuously sampled to ensure stratigraphic control. Borehole samples should be classified according to their lithology or pedology by an experienced professional in geology. Care should be taken to ensure that samples of every geologic formation, especially all confining layers, are collected, and that the nature of stratigraphic contacts is determined.

6.4.5 Well Casing and Screen Materials

Fig. 6-15 is a drawing of a typical monitoring well commensurate with EPA guidance. A casing and well screen are installed in a groundwater monitoring well for several reasons: to provide access from the surface of the ground to some point in the subsurface, to prevent borehole collapse, to permit groundwater level measurements and groundwater sampling, and (for casing) to prevent hydraulic communication between zones within the subsurface. Access to the monitored zone is through the casing and into either an open borehole or the screened intake.

Fig. 6-15. Cross-section of a typical monitoring well.

Monitoring well casing and screen materials should meet the following performance specifications:

- Monitoring well casing and screen materials should maintain their structural integrity and durability in the environment in which they are used over their operating life.

- Monitoring well casing and screen materials should be resistant to chemical and microbiological corrosion and degradation in contaminated and uncontaminated waters.

- Monitoring well casings and screens should be able to withstand the physical forces acting upon them during and following their installation, and during their use—including forces due to suspension in the borehole, grouting, development, purging, pumping, and sampling, and forces exerted on them by the surrounding geologic materials.

- Monitoring well casing and screen materials should not chemically alter groundwater samples, especially with respect to the analytes of concern, as a result of their sorbing, desorbing, or leaching analytes. For example, if a metal such as chromium is an analyte of interest, the well casing or screen should not increase or decrease the amount of chromium in the groundwater. Any material leaching from the casing or screen should not be an analyte of interest or interfere in the analysis of an analyte of interest.

In addition, monitoring well casing and screen materials should be relatively easy to install into the borehole during construction of the monitoring well. Table 6-10 provides a summary of recommendations for the use of certain well casing materials under various physical and geochemical conditions which may be encountered.

6.4.6 Well Intake Design

The intakes of monitoring wells should be designed and constructed to (1) accurately sample the aquifer zone that the well is intended to sample, (2) minimize the passage of formation materials (turbidity) into the well, and (3) ensure sufficient structural integrity to prevent the collapse of the intake structure.

The goal of a properly completed monitoring well is to provide low turbidity water that is representative of groundwater quality in the vicinity of the well. Although wells completed in rock often do not require screens, the majority of wells installed for RCRA purposes are completed in unconsolidated sediments.

EPA prefers that well screens be kept to the minimum length appropriate for intercepting a contaminant plume, especially in a high-yielding aquifer. The screen length generally should not exceed 10 ft.

Table 6-10. General recommendations for selection of well casing materials

	Do not use	Use
1.	PTFE if well depth exceeds 225-375 ft (68.5-114 m)	PVC, ABS, SS
2.	PVC or ABS if well depth exceeds 1200-2000 ft (366-610 m)	SS
3.	SS if pH < 7.0	PVC, ABS, or PTFE
4.	SS if DO > 2 ppm	PVC, ABS, or PTFE
5.	SS if $H_2S \geq 1$ ppm	PVC, ABS, or PTFE
6.	SS if T.D.S. > 1000 ppm	PVC, ABS, or PTFE
7.	SS if $CO_2 > 50$ ppm	PVC, ABS, or PTFE
8.	SS if $Cl^- > 500$ ppm	PVC, ABS, or PTFE
9.	PVC if a neat PVC solvent/softening agent[a] is present or if the aqueous concentration of the PVC solvent/softening agent exceeds 0.25 times its solubility in water	SS, PTFE
10.	Solvent bonded joints for PVC casings	Threaded PVC casings
11.	Welded stainless joints	Threaded SS casings
12.	Any PVC well casing that is not NSF-ASTM approved - D-1785 and F-480	ASTM-NSF approved PVC well casings - D-1785 and F-480
13.	Any stainless steel casing that is not ASTM approved - A312	ASTM approved SS 304 and SS 316 casings - A312
14.	Any ABS well casing that is not ASTM approved	ASTM approved ABS casings - F-480

[a]Known PVC solvents/softening agents include: Tetrahydrofuran, cyclohexane, methyl ethyl ketone, methyl isobutyl ketone, methylene chloride, trichloromethane, 1,1-dichloroethane, 1,1,1-trichloroethane, trichloroethylene, benzene, toluene, acetone, and tetrachloroethylene.

PTFE = polytetrafluoroethylene
PVC = polyvinyl chloride
ABS = acrylonitrile-butadiene-styrene
SS = stainless steel
DO = dissolved oxygen
T.D.S. = total dissolved solids

Well screen slot size should be selected to retain from 90% to 100% of the filter pack material in artificially filter-packed wells, or from 50% to 100% of the formation material in naturally packed wells, unless it can be demonstrated that the water is turbidity-free. The EPA emphasizes that filtering a sample subsequent to its collection is not the solution for dealing with turbidity in an improperly designed well. Furthermore, well screens should be factory-slotted. Manually slotting screens in the field should not be performed under any circumstances.

The annular space between the borehole wall and the screen or slotted casing should be filled in a manner that minimizes the passage of formation material into the well. Filter packs/pack material should be used for this purpose considering the following factors:

- An artificial filter pack is appropriate for most geologic settings.
- Filter pack material should be chemically inert.
- Filter pack material should be well rounded and of uniform grain size.
- Filter pack material should be installed in a manner that prevents bridging and particle-size segregation.
- At least two units of filter pack material should be installed between the wall screen and the borehole wall.
- Prior to installation of the annular seal, a 1-to-2-ft layer of chemically inert fine sand should be placed over the filter pack to prevent the intrusion of annular or surface sealants into the pack.

With regulatory concurrence, filtered samples may be a solution for wells that are slow to recharge. In these cases, both filtered and unfiltered samples could be analyzed. If filtering is not an option, there are methods such as micropurging, or using low flow pumps, that may be utilized to reduce turbidity. Because of the increased time for sample collection, these methods are generally more costly than traditional methods.

6.4.7 Annular Sealants

Proper sealing of the annular space between the well casing and the borehole wall is required (§264.97(c)) to prevent contamination of samples and the groundwater. Adequate sealing will prevent hydraulic connection within the well annulus. The materials used for annular sealants should be chemically inert, with the highest anticipated concentration of chemical constituents expected in the groundwater at the facility. In general, the permeability of the sealing material should be one to two orders of magnitude lower than the least permeable part of the formation in contact with the well. The precise volume of annual sealants required should be calculated and recorded before placement, and the actual volume used should be determined and recorded during well construction. Any significant discrepancy between the calculated volume and the actual volume should be explained.

6.4.8 Surface Completion

In general, completing a monitoring well will involve installing the following components:

- Surface seal
- Protective casing, utility vault, or meter box
- Ventilation hole(s)
- Drain hole(s)
- Cap
- Lock
- Guard posts

Monitoring wells are commonly completed at the surface in one of two ways: as above-ground completions, or as flush-to-ground completions. The purposes of both types of completion are to prevent infiltration of surface runoff into the well annulus and to prevent accidental damage or vandalism of the well.

6.4.9 Well Surveying

The location of all wells should be surveyed by a licensed professional surveyor (or equivalent) to determine their X-Y coordinates as well as their distances from the units being monitored and their distances from each other. A State Plane Coordinate System, Universal Transverse Mercator System, or Latitude/Longitude should be used, as approved by the regulatory agency. The survey should also note the coordinates of any temporary benchmarks. A surveyed reference mark should be placed on the top of the well casing, not on the protective casing or the well apron, for use as a measuring point because the well casing is more stable than the protective casing or well apron (both the protective casing and the well apron are more susceptible to frost heave and spalling). The height of the reference survey datum, permanently marked on top of the inner well casing, should be determined within ±0.01 ft in relation to mean sea level, which in turn is established by reference to an established National Geodetic Vertical Datum. The reference marked on top of inner well casings should be resurveyed at least once every 5 years, unless changes in groundwater flow patterns/direction or damage caused by freeze/thaw or desiccation processes is noted. In such cases, the regulator may require that well casings be resurveyed on a more frequent basis.

6.4.10 Well Development

All monitoring wells should be developed to create an effective filter pack around the well screen, to rectify damage to the formation caused by drilling, to remove fine particles from the formation near the borehole, and to assist in restoring the natural water quality of the aquifer in the vicinity of the well. Development stresses the formation around the screen, as well as the filter pack, so that mobile fines, silts, and clays are pulled into the well and removed. The process of developing a well creates a graded filter pack around the well screen. Development is also used to remove any foreign materials (drilling water, mud, etc.) that may have been introduced into the well borehole during drilling and well installation, and to aid in the equilibration that will occur between the filter pack, the well casing, and the formation water.

The common methods for developing wells include pumping and overpumping, backwashing, surging with a surge block, bailing, jetting, airlift pumping, and air surging.

6.4.11 Documentation of Well Design, Construction, and Development

Information on the design, construction, and development of each well should be compiled. Such information should include: (1) a boring log that documents well drilling and associated sampling and (2) a well construction log and well construction diagram ("as built").

6.4.12 Specialized Well Design

Specialized monitoring well designs should be used if dedicated pumps are to be used to withdraw groundwater samples. Dedicated pumps should be fluorocarbon resin or stainless steel positive gas displacement bladder pumps, or equivalent devices approved by the regulator. The design of the dedicated sampling system should allow access to the well for the purpose of conducting aquifer tests, maintaining the well (e.g., redevelopment procedures), and making water-level measurements. Dedicated sampling systems should be periodically inspected to ensure that the equipment is functioning reliably. Samples should be withdrawn from the system to evaluate the operation of the equipment, and the equipment should be checked for damage.

6.5 SAMPLING PROCEDURES

Sampling procedures for OB/OD closures should be commensurate with applicable EPA, state, and Army guidance (see Fig. 6-16). Specifications for sampling procedures are provided in the following EPA guidance documents:

- Test Methods for Evaluating Solid Waste SW-846 (USEPA, December 1996)
- Interim Final RCRA Facility Investigation Guidance (USEPA, May 1989b)
- RCRA Ground-Water Monitoring: Draft Technical Guidance (USEPA, November 1992)
- Soil Sampling Quality Assurance User's Guide (USEPA, May 1984)

State guidance should also be considered, as available and applicable.

The USACE has prepared a standard set of instructions for the following types of environmental sampling:

- Groundwater sampling
- Surface water sampling
- Potable water sampling
- Sediment sampling
- Soil sampling
- Surficial sampling

These sampling instructions are included as appendices in Requirements for the Preparation of Sampling and Analysis Plans, EM 200-1-3 (U.S. Army, September 1994). In general, these sampling procedures are consistent with EPA guidance and can be used as the primary basis for OB/OD closure sampling. However, site-specific and lead regulatory agency requirements may necessitate revisions to these generic sampling instructions.

Fig. 6-16. Specification of sampling procedures.

6.6 INVESTIGATION-DERIVED WASTE

Investigation-derived waste (IDW) should be managed commensurate with guidance provided in Sect. 9.2.2.5 (see Fig. 6-17).

Fig. 6-17. Approach for the disposal of investigation-derived waste.

6.7 ANALYTES

Selection of analytes for OB/OD closure sampling activities should involve the following components:

- Generic OB/OD analyte list
- Pre-closure site-specific analytes (an abbreviated list)
- Post-closure site-specific analytes (i.e., based on indicators)

This approach is illustrated in Fig. 6-18.

6.7.1 Generic OB/OD Analyte List

The identification of potential target analytes due to OB/OD operations has been discussed in Sect. 3. In summary, the generic list of target analytes is as follows:

- Energetics
- Other semivolatiles (i.e., base, neutral and acid extractables—BNA)
- RCRA metals
- Other metals
- Other potential contaminants

Principal energetics of concern (considering prevalence and the availability of health criteria) include the following:

- RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)
- HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)
- TNT (2,4,6-Trinitrotoluene)
- DNT (2,4- and 2,6-Dinitrotoluene)
- DNB (1,3-Dinitrobenzene)
- HCE (Hexachloroethane)
- Tetryl (Methyl-2,4,6-trinitrophenylnitramine)
- TNB (1,3,5-Trinitrobenzene)
- Nitrocellulose

The following additional target analytes for energetics should be considered for OB/OD closures on a case-by-case basis, taking account of knowledge of site waste treatment/disposal practices and regulatory negotiations:

- TNG (Trinitroglycerol [nitroglycerin])
- PETN (Pentaerythritol tetranitrate)
- Nitroglycerin (NG)
- NQ (Nitroguanidine)
- WP (White phosphorus)
- EGDN (Ethylene glycol dinitrate)

- PGDN (Propylene glycol dinitrate)
- Picric acid
- Picramic acid

The energetics listed above are not considered standard target analytes, since they generally require special analytical methods and additional analytical costs.

Other potential semivolatiles of concern have been identified in Table 3-2. Hexachloroethane (HCE) may also be an appropriate energetic semivolatile target analyte on a case-by-case basis and is included in the standard BNA list. Metals of potential concern include the following (which represent metals that typically are part of the composition of munitions, propellants, and explosives and associated casings) (U.S. Army, May 1995):

- Aluminum
- Antimony
- Arsenic
- Barium
- Boron
- Calcium
- Chromium
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Nickel
- Potassium
- Silver
- Sodium
- Strontium
- Tin
- Titanium
- Zinc

Arsenic, barium, chromium, lead, nickel, and silver are RCRA-regulated wastes included in the above list of potential contaminants from OB/OD. Other RCRA metals are cadmium, mercury, and selenium. While these metals are not typical constituents of munitions, explosives, and propellants, sampling of them may be required by the lead regulatory agency.

Nitrate is another RCRA-regulated waste parameter which is also a major component of energetics and associated products of incomplete combustion.

Cyanide is a potential product of incomplete combustion of energetics.

There is the potential for the emission of chlorinated compounds (e.g., dioxins and furans) associated with the treatment of chlorinated propellants. The emission factors for these compounds have been the object of recent OB/OD BangBox tests. Therefore, the need to include dioxins/furans as target analytes should be evaluated on a site-specific basis.

Herbicides have been used at some sites to control vegetation in the vicinity of OB/OD areas as a fire prevention measure. Therefore, herbicides should be considered a potential target analyte as appropriate based on their prior use.

OB/OD tests, including BangBox emission studies, have confirmed that VOCs are not considered significant contaminants. At some sites, however, supplemental liquid fuels have been used for OB operations, and other past treatment or disposal activities may have involved VOCs. Therefore, for these cases, it may be appropriate to sample for VOCs or screening compounds such as benzene, toluene, and xylene (BTX) or benzene, toluene, ethyl benzene, and xylene (BTEX). The selection of these target analytes should be considered on a case-by-case basis, taking into account knowledge of site waste treatment/disposal practices and regulatory negotiations.

Total organic content (TOC) and pH should also be included as target analytes. These parameters are routinely used to evaluate water quality at RCRA facilities. Soil TOC and pH are needed input for constituent migration modeling purposes.

The State of Kansas has indicated that the following should also be considered as target analytes for OB/OD closures:

- Molydenum
- Tungsten
- Tetranitrocarbazole

However, these chemicals should not be considered as generic target analytes (because of the lack of standard analytical methods and lack of toxicity criteria).

6.7.2 Pre-Closure Site-Specific Analytes

An abbreviated target analyte list should be identified based on site-specific information for the pre-closure sampling program. Information from previous site investigations should be evaluated. If previous sampling results are not available, it may be useful to conduct preliminary sampling and analysis of the OB/OD source area (i.e., the "hot spots"). The source sampling should be based on the generic OB/OD target analyte list. These site lists should be used to prioritize and select constituents of potential concern (i.e., an abbreviated list conforms to the generic list) based on the EPA methodology presented in Sect. 8.2.1.1.

For example, OB/OD constituents of potential concern (CPCs) on an Army-wide basis are typically barium, lead, 2,4-DNT, 2,6-DNT, HMX, RDX, and 2,4,6-TNT. But it is necessary to evaluate initially the more comprehensive list of target analytes on a site-specific basis and to obtain data to support elimination of target analytes that do not present a significant risk.

In one particular OB clean closure case, EPA Region 5 has recommended limiting target analytes to energetics and metals for pre-closure soil sampling. But a comprehensive global target analyte list would be needed for soil verification sampling (if excavation is needed) as well as for groundwater samples.

6.7.3 Post-Closure Site-Specific Analytes

The potential use of indicator analytes should be considered for post-closure (i.e., verification) sampling and analysis. The post-closure sampling will involve verification sampling for clean closures and long-term groundwater monitoring for landfill closures. Again, the risk-based methodology for selecting indicator constituents discussed in Sect. 8.2.1.1 should be applied. For example, TNT or DNT may be candidate indicators for energetics and lead for metals. The indicators should be selected such that acceptable levels for these contaminants would ensure (based on pre-closure analytical results) that clean criteria for all other constituents would be achieved.

In the EPA Region 5 example discussed in Sect. 6.7.2, a comprehensive global target analyte list may be needed if verification sampling is limited to a subset of indicator parameters.

6.8 ANALYTICAL METHODS

The approach for the selection of analytical methods for target analytes is summarized in Fig. 6-19. The primary reference for these methods is the latest version of Test Methods for Evaluating Solid Waste, SW-846 (USEPA, December 1996).

Laboratory analyses of samples will be the primary analytical approach for the pre-closure sampling program. Analytical requirements for OB/OD target analytes are summarized in Table 6-11.

The concentration of 2,4-DNT in soil and sediment samples can be determined using two different methodologies, EPA Methods 8270 and 8330. A comparison of the two methods conducted by the USACE Mobile District demonstrated a wide degree of variability in the results for many of the samples evaluated. One reason for this was the difference between the minimum detection limits. The minimum detection limit for Method 8270 is 330 μg/kg, while for Method 8330 it is 30 μg/kg. With a lower detection limit, Method 8330 was more sensitive to the changes in concentration. A second reason was the size of the aliquot (fraction of sample) used for each method. Method 8330 uses a smaller fraction of sample. In addition, dinitrotoluene is generally present in soil as randomly distributed particles. Therefore, in a small sample, the presence of a particle could portray a relatively high concentration; while in a larger sample, the presence of particles is average, producing a concentration more indicative of the true average. However, larger sample sizes can be taken as long as the soil to solvent ratio is maintained. While the precision of the results for particulate 2,4-DNT by Method 8330 was such that the results were unreliable, this is the only method available for many explosives and propellants. However, Method 8270 (which is typically needed anyway to characterize semivolatiles at OB/OD sites), is also available for supplemental 2,4-DNT results and is less susceptible to analytical randomness.

Toxicity Characteristic Leaching Procedure (TCLP) analysis should be performed only on soil or sediment samples in which the total metals or 2,4-DNT analytical results were 20 times or higher than the toxicity characteristic (TC) maximum concentration limit listed in 40 CFR 261.24, Table 1. The factor of 20 was determined by the 20:1 dilution which is performed during the TCLP analysis, where 100 grams of soil are added to 2 liters of water. If all of the contaminants in the sample had dissolved, any sample with a concentration more than 20 times the TC maximum concentration limit would exceed the limit for toxicity and would be a potential hazardous waste; thus, any sample exceeding this TC limit should be analyzed using TCLP analysis. This represents a cost-effective screening approach for TCLP analyses.

Screening analytical methods may be appropriate and useful for some post-closure sampling applications. EPA SW-846 field screening methods are available for TNT and RDX. These methods are summarized in Table 6-12. Various commercial energetics field screening kits are available for EPA Method 4050 (TNT Explosives in Water and Soils by Immunoassay), 4051 (RDX in Soil and Water by Immunoassay), and 8615 (Colorimetric Screening Methods for TNT in Soil). Additional information regarding onsite analytical methods for explosives in soil is presented in Appendix J.3 (USEPA, November 1996b).

Table 6-11. Analytical requirements for OB/OD target analytes

Parameter	EPA method[a]	Holding times[b]	Detection limits: Aqueous	Detection limits: Soil	Minimum sample volume required
Energetics	Aqueous/soil 8330[c]	7 days to extraction, 40 days to analysis	0.004-0.1 mg/L	0.01 - 2.2 mg/kg	Aqueous 2-1L A.J.[d] Soil 1-4 oz CWM[e]
DNT	Soil 1311 (extraction) 8270 (analysis)	After extraction, 14 days to analysis	NR[f]	0.04 mg/L (extract)	Soil 16 oz CWM
Semivolatiles (base, neutral, and acid extractables)	Aqueous 3510 or 3520 (extraction) 8270 (analysis) Soil 3540 or 3550 (extraction) 8270 (analysis)	7 days to extraction, 40 days to analysis (both matrices)	0.006 - 0.02 mg/L	0.2 - 0.66 mg/kg	Aqueous 2-1L A.J. Soil 8 oz CWM
Total metals[g]	Aqueous/Soil	6 months (except mercury, 28 days and chromium VI, 24 hours)			All metals except chromium VI and mercury Aqueous 1L HDPE[h] Soil 8 oz CWM
Aluminum	6010		0.09 mg/L	9 mg/kg	
Antimony	6010		0.064 mg/L	6 mg/kg	
Arsenic	7060		0.001 mg/L	0.2 mg/.kg	
Barium	6010		0.004 mg/L	0.4 mg/kg	
Boron	6010		0.005 mg/L	0.5 mg/kg	
Cadmium	6010		0.008 mg/L	0.8 mg/kg	
Chromium (Total)	6010		0.014 mg/L	1 mg/kg	
Chromium VI	7196		0.5 mg/L	20 mg/kg	Aqueous 250 mL HDPE Soil 8 oz CWM
Copper	6010		0.012 mg/L	1 mg/kg	
Iron	6010		0.014 mg/L	1 mg/kg	
Lead	7421		0.001 mg/L	0.2 mg/kg	
Magnesium	6010		0.06 mg/L	6 mg/kg	

Table 6-11. (Continued)

Parameter	EPA method[a]	Holding times[b]	Detection limits Aqueous	Detection limits Soil	Minimum sample volume required
Manganese	6010		0.004 mg/L	0.4 mg/kg	
Mercury	7471		0.0001 mg/L	0.1 mg/kg	Aqueous 250 mL HDPE Soil 8 oz CWM
Nickel	6010		0.03 mg/L	3 mg/kg	
Potassium	6010		0.01 mg/L	5 mg/kg	
Selenium	7740		0.002 mg/L	0.4 mg/kg	
Silver	6010		0.014 mg/L	1 mg/kg	
Sodium	6010		0.058 mg/L	58 mg/kg	
Strontium	6010		0.0006 mg/L	0.06 mg/kg	
Tin	7870		0.8 mg/L	80 mg/kg	
Titanium	283.1[i]		0.005 mg/L	0.5 mg/kg	
Zinc	6010		0.004 mg/L	0.05 mg/kg	
Cyanide	Aqueous/soil	14 days	10 mg/L	10 mg/L	Aqueous 1L HDPE Soil 4 oz CWM
Nitrates/nitrites	Aqueous/soil 353.2[i]	28 days (both matrices)[j]	0.05 mg/L	0.5 mg/kg	Aqueous 250 mL HDPE Soil 8 oz CWM
TCLP semivolatiles	Soil 1311 (extraction) 8270 (analysis)	After extraction, 14 days to analysis	0.006 - 0.02 M	0.2 - 0.66 mg/kg	Soil 16 oz CWM
TCLP metals	Soil 1311 (extraction)	6 months (except mercury 28 days)			Soil 16 oz CWM
Arsenic	7060		0.001 mg/L	0.2 mg/kg	
Barium	6010		0.004 mg/L	0.4 mg/kg	
Cadmium	6010		0.008 mg/L	0.8 mg/kg	
Chromium (Total)	6010		0.14 mg/L	1 mg/kg	
Lead	7421		0.001 mg/L	0.2 mg/kg	
Mercury	7471		0.0001 mg/L	0.1 mg/kg	
Selenium	7479		0.002 mg/L	0.4 mg/kg	

Table 6-11. (Continued)

Parameter	EPA method[a]	Holding times[b]	Detection limits		Minimum sample volume required
			Aqueous	Soil	
Silver	6010		0.014 mg/L	1 mg/kg	
TCLP nitrates/nitrites	Soil 1311 (extraction) 383.2 (analysis)[i]	28 days[j]	NR	0.05 mg/L (extract)	
Dioxins and furans (screen)	Aqueous/soil 8280	7 days to extraction, 28 days to analysis	0.44 - 3.93 ppt (ng/L)[k]	0.00011 - 0.0023 mg/kg	Aqueous 2-112 L A.J. Soil 8 oz CWM
Chlorinated herbicides	Aqueous/soil 8150	14 days to extraction, 28 days to analysis	0.00007 - 0.249 mg/L	0.0047 - 167 mg/kg	Aqueous 2-112 L A.J. Soil 8 oz CWM
Benzene, toluene, xylene (BTX)	Aqueous/soil 8260A	14 days (7 days for aqueous sample if unpreserved)	0.001 mg/L	0.005 mg/kg	Aqueous 2-40 mL glass vials Soil 4 oz CWM
PH	Soil 9045	Analyze as soon as possible	NR	N/A[l]	Soil 4 oz CWM
Total organic carbon	Soil Walkley-Black[m]	28 days	NR	130 mg/kg	Soil 4 oz CWM

[a]USEPA Test Methods for Evaluating Solid Waste, SW-846, Third Edition, Update 1, Revision 1, 1995c.

[b]Maximum allowable holding times are measured from the date of sample collection to the date of preparation/analysis.

[c]A modified Method 8330 may be used to expand the target analyte list. A relatively new SW-846 method for energetics is 8095, which is a gas chromatographic method for all the target energetics and is being included in update IV of SW-846 and is available for use.

[d]A.J. - Amber jug.

[e]CWM - Clear wide-mouth (bottle).

[f]NR - Not required.

[g]For the 6010 analysis, preparation methods 3005 or 3010 are applicable for water samples, while 3050 is applicable for soil samples. Method 3050 is also applicable for preparation of soil samples undergoing analysis by the 7000 series methods. For hexavalent chromium, Method 3060A is applicable for the preparation of soil samples.

Table 6-11. (Continued)

[h]HDPE = High-density polyethylene bottles.

[i]EPA March 1979, Methods for Chemical Analysis of Water and Wastes, EPA-600/4-799-020, revised March 1983.

[j]For the nitrates/nitrites in soils, the samples must be extracted within 48 hours. If the laboratory preserves the extract (H2SO4 to pH < 2), the holding time is extended to 28 days. Preserving the aqueous samples also extends the holding time to 28 days.

[k]ppt = Parts per trillion.

[l]N/A = Not applicable.

[m]Walkley Black 1982, 2nd Edition, Method 29-3.5.2.

Table 6-12. Summary of EPA screening methods for energetics

Parameter	EPA method[a]	Background area	
TNT	Soil 8515 (colorimetric)	Soil	1 mg/kg
TNT	Soil/aqueous 4050 (immunoassay)	Aqueous	0.005 mg/L
		Soil	0.5 mg/kg
RDX	Soil/aqueous 4051 (immunoassay)	Aqueous	0.005 mg/L
		Soil	0.5 mg/kg

[a]USEPA, Test Methods for Evaluating Solid Waste, SW-846, Revision 0, 1995c.

7. SITE INVESTIGATION DATA ANALYSIS

Analysis of site investigation data to support OB/OD closures includes the following components (see Fig. 7-1):

- Data validation
- Statistical significance compared to background
- Data presentation

Data analysis results provide input to the risk assessment process and the definition of closure performance standards. Therefore, these data analysis results should be compared to DQOs as specified in the QAPP.

7.1 DATA VALIDATION

An adequate QA/QC program requires the identification and quantification of all sources of error associated with each step of a sampling program so that the resulting data will be of known quality. The components of error, or variance, include those associated with field sampling and sample preparation, extraction, and analysis in the laboratory. All items except sampling are addressed by the analytical laboratory QA/QC program. For monitoring a relatively heterogeneous medium such as soil, the sampling component of variance will usually significantly exceed the analysis component.

Each laboratory analyzing sample should have a QA/QC plan for each parameter of interest. Data validation is the procedure of checking and assessing laboratory and field QA/QC data. EPA defines "data validation" as a systematic process that consists of data editing, screening, checking, auditing, verifying, certifying, and reviewing (USEPA, 1994a,b). Data validation is a process to determine whether analytical data meet both the analytical method requirements and the associated project objectives. Data reduction, validation, and reporting are basic steps in the control and processing of field and laboratory data. Data validation consists of a review of an analytical data package (i.e., results and QA/QC documentation) with respect to sample receipt and handling, analytical methods, data reporting and deliverables, and document control. The quality of data generated by a laboratory is important, is an integral part of an investigation, and should be clearly tied to project goals. The net result is a data package that has been carefully reviewed for its adherence to prescribed requirements and is suitable for its intended use. Data validation thus plays a major role in determining the confidence with which key technical evaluations may be made. Validated data are legally defensible. The lead regulatory agency should be contacted to establish specific data validation requirements for closure.

Data validation also includes a review of analytical data from field QC samples. These samples include field blanks, equipment rinsate blanks, trip blanks, and field duplicates. Field blanks, obtained by sampling the water used in decontamination during the field investigation, are used to determine whether this water may be contributing to sample contamination.

Equipment rinsate blanks are obtained under representative field conditions by running analyte-free water through or over sample collection equipment (auger, trowel, etc.) after decontamination. Equipment rinsate blanks are used to assess the effectiveness of decontamination. Trip blanks are included when analyzing for VOCs and are prepared or provided by the laboratory. Trip blanks are used to indicate whether a source of volatile organics in the environment has entered the sample. Field duplicates are two samples collected independently at a sampling location or a single sample split into two portions. Field duplicates are obtained during a single act of sampling and are used to assess the overall precision of the sampling and analysis program. An overview of data validation requirements for organic analytical data and inorganic analytical data is provided in Fig. 7-2.

7.1.1 Organic Analytical Data

Procedures for validation of organic data (including energetics) have been established by EPA on a national level (USEPA, February 1994a). Some EPA regions and states have made modifications to the national validation procedures. Organic analytical data (volatiles, semivolatiles, and pesticides/polychlorinated biphenyls [PCBs]) are evaluated based on the following criteria: holding times, gas chromatograph/mass spectrometer (GC/MS) tuning and mass calibration, initial and continuing calibration, laboratory and field blank analyses, laboratory and field duplicate analyses, surrogate spikes, matrix spike (MS) and matrix spike duplicate (MSD) analyses, laboratory control samples, internal standards, target compound identification, and compound quantitation and quantitation limits. The objectives of each of these criteria are discussed below.

Holding Times

The objective of this evaluation is to ascertain the validity of results based on the holding time of the sample from the time of collection to the time of analysis. If holding times are exceeded, the integrity of the sample may be compromised.

Instrument Performance Checks (Tuning)

GC/MS instrument performance checks are performed to ensure mass resolution, compound identification, and sensitivity. Performance checks on the GC with an electron capture detector (ECD) system, used for analysis of pesticides and PCBs, are performed to ensure adequate resolution and instrument sensitivity. Tuning data that do not meet performance criteria need to be evaluated to determine whether the deviation is significant and would affect the sample results.

Initial and Continuing Calibration

Satisfactory instrument calibration is needed to ensure that the instrument is capable of producing acceptable qualitative and quantitative data. Initial calibration demonstrates that the instrument is capable of acceptable performance in the beginning of the analytical run and of producing a linear calibration curve. Continuing calibration establishes the relative response factors on which the quantitations are made and checks instrument performance on a day-to-day basis.

Blanks

The purpose of laboratory and field blank analysis is to determine the existence and magnitude of contamination resulting from laboratory or field activities. If problems with any blank exist, all associated data must be carefully evaluated to determine whether there is an inherent variability in the data or if the problem is an isolated occurrence.

Duplicates

Laboratory duplicate analyses are indicators of laboratory precision. Field duplicate samples are an indication of overall precision. Analysis of field duplicates measures both field and laboratory precision.

Surrogate Spikes

Laboratory performance on individual samples is established by means of spiking activities. All samples are spiked with system monitoring compounds. Data are qualified if the spike recovery is out of specification.

Matrix Spikes/Matrix Spike Duplicates

Data for MS/MSD are generated to determine long-term precision and accuracy of the analytical method on various matrices and to demonstrate acceptable compound recovery by the laboratory at the time of sample analysis. These data alone cannot be used to evaluate precision and accuracy of individual samples; however, the data can be used in conjunction with other available QA/QC information.

Laboratory Control Samples

Data for laboratory control samples are generated to provide information on the accuracy of the analytical method and on the laboratory performance.

Internal Standards

The internal standards performance criterion ensures that GC/MS sensitivity and response are stable during each analysis.

Target Compound Identification

The objective of this criterion is to minimize the number of erroneous identifications of compounds. An erroneous identification can be either a false positive (reporting a compound present when it is not) or a false negative (not reporting a compound that is present).

Compound Quantitation and Quantitation Limits

The objective is to ensure that the reported quantitation results and quantitation limits are accurate.

7.1.2 Inorganic Analytical Data

Procedures for validation of inorganic data have been established by the EPA on a national level (USEPA, February 1994b). Some EPA regions and states may have made modifications to the national validation procedures. Inorganic analytical data (metals and cyanide) are evaluated based on the following criteria: holding times, calibration, laboratory and field blanks, inductively coupled plasma (ICP) interference check sample (ICS), laboratory control sample (LCS), laboratory and field duplicate sample analysis, spike sample analysis, graphite furnace atomic absorption (GFAA) QC, and ICP serial dilution. The objectives of each of these criteria are discussed below:

Holding Times

The objective of this evaluation is to ascertain the validity of results based on the holding time of the sample. If holding times are exceeded, the integrity of the sample may be compromised.

Calibration

Method requirements for satisfactory instrument calibration are established to ensure that the instrument is capable of producing acceptable quantitative data. Initial calibration demonstrates that the instrument is capable of acceptable performance at the beginning of the analytical run. Continuing calibration verification establishes that the initial calibration is still valid by checking the performance of the instrument on a continuing basis.

Blanks

Blank analysis results are assessed to determine the existence and magnitude of contamination resulting from laboratory or field activities. If problems with any blank exist, all associated data must be carefully evaluated to determine whether or not there is an inherent variability in the data or if the problem is an isolated occurrence not affecting other data.

ICP Interference Check Sample (ICS)

The ICS verifies the laboratory's interelement and background correction factors.

Laboratory Control Sample (LCS)

The LCS serves as a monitor of the overall performance of each step during the analysis, including the sample preparation.

Duplicate Sample Analysis

Laboratory duplicate sample determinations are used to demonstrate acceptable method precision by the laboratory at the time of analysis. Laboratory duplicate analyses are also performed to generate data to determine the long-term precision of the analytical method on various matrices. Field duplicate samples may be taken and analyzed as an indication of overall precision. Analysis of field duplicates is a measure of both field and lab precision.

Spike Sample Analysis

The spike sample analysis is designed to provide information about the effect of each sample matrix on the sample preparation procedures and the measurement methodology.

Graphite Furnace Atomic Absorption QC

Because of the nature of the GFAA technique, special analytical procedures are required for the quantitation of samples. Duplicate injections and multiple level post-digestion spikes are used to determine the precision and accuracy of the individual analytical determinations.

ICP Serial Dilution

The serial dilution of samples quantitated by ICP determines whether significant physical or chemical interferences exist due to sample matrix.

7.2 STATISTICAL SIGNIFICANCE COMPARED TO BACKGROUND

Validated analytical data for each sampling medium should be evaluated for significance relative to background concentrations (see Fig. 7-3). Specifically, the existence of contamination should be determined by a statistical comparison with background conditions using the most current EPA guidance as currently provided in Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities - Draft Addendum to Interim Final Guidance (USEPA, July 1992). This statistical guidance is quite detailed and complex. Therefore, the EPA guidance document should be directly consulted for the selection and implementation of statistical analysis procedures on a site-specific basis. State regulatory agencies may have specific preferences regarding which statistical methods are used.

7.3 DATA PRESENTATION

Site investigation data should be presented in a format which facilitates data interpretation and supports cleanup decisionmaking. Data presentation involves the following:

- Laboratory data presentation
- Comparison to background data presentation
- Comparison to screening or risk-based criteria

These items are identified in Fig. 7-4 and discussed in the subsections which follow.

7.3.1 Laboratory Data Presentation

The laboratory data for each sample, including QC samples, should be listed in an appendix (see example format in Table 7-1). These data should be presented in a spreadsheet format for each medium (e.g., groundwater, soil). The analytical parameters should be listed vertically by analytical families (e.g., volatiles, semivolatiles, pesticides/PCBs, and metals). Column headings for each sample should include the sampling location, sampling depth, and sample number, as well as sample collection and analysis dates. The spreadsheet should also include the detection limit, concentration results and units, as well as data qualifiers from the data validation process.

A discussion of the results, including results of background sampling, should be provided in the main body of the report. Items that could be discussed include the frequency of detection, the concentration range for positive detections, average concentrations, and location(s) of maximum detections. This could be in the form of a summary table supported by text containing supporting discussions.

7.3.2 Comparison to Background Data Presentation

Validated data used for the identification of sampling results which are considered statistically significant (compared to background) should be summarized. An example format for the comparison of validated data to background data is presented in Table 7-2.

Data should be presented for each sampling location within the various study areas. Background data should also be provided. (These study areas correspond to those discussed in Sect. 6 regarding sampling strategies for site investigations.) Medium-specific concentrations for each analyte should be provided. In addition, statistical parameters (pursuant to the EPA guidance identified in Sect. 7.2) used to characterize the sampling results should be presented. The tabular summaries should also denote those sampling/analytical results that are considered statistically significant compared to background.

Table 7-1. Example format for laboratory data presentation

Analyte	Sampling medium	Sample type	Sampling Location	Sampling Depth	Sampling date	Analysis date	Sample no.	Detection limit	Analytical concentration	Concentration units	Data qualifiers
Analyte a											
Analyte b											
Analyte c											
Analyte d											
etc.											

Table 7-2. Example format for comparison of validated data to background data presentation

	Study area a					Study area n					Background				
	Location				Std.	Location				Std.	Location				Std.
Analyte	A-1	A-2	A-n	Mean	dev.	N-1	N-2	N-n	Mean	dev.	Bk-1	Bk-2	Bk-n	Mean	dev.
Analyte a															
Analyte b															
Analyte c															
Analyte d															
etc.															

7.3.3 Comparison to Screening or Risk-Based Criteria

Summary tables should be prepared for comparison of statistically significant data (compared to background) to screening or risk-based criteria. An example format for these tabular summaries is indicated in Table 7-3. The emphasis should be on the comparison of study areas to both background and cleanup criteria. Values which exceed the screening or risk-based criteria should be denoted since they indicate the potential need for cleanup actions.

Geostatistical techniques should also be considered for presentation of data results. (ASTM, 1996a; ASTM, 1996b; ASTM, 1996c). For example, kriging methods can be used to identify and delineate contamination areas that exceed risk-based criteria. Kriging is particularly adaptable to the use of geographic information system capabilities in conjunction with a PC database of validated analytical results. Kriging methods can also be used to quantify the confidence levels associated with the contaminated areas identified. Kriging also can identify those areas where additional sampling may be warranted.

Table 7-3. Example format for comparison of statistically significant (compared to background) data to screening or risk-based criteria

Analyte	Study area a	Study area b	Study area n	Background	Screening or risk-based criteria
Analyte a					
Analyte b					
Analyte c					
Analyte d					
etc.					

8. CLEAN CLOSURE AND RISK-BASED PERFORMANCE STANDARDS

Site investigation results (as discussed in Sects. 6 and 7) are needed to determine site-specific cleanup criteria for clean closures. Alternative clean closure performance standards have been discussed in Sect. 2.2.1. Currently the most prevalent approach for defining clean closure standards has been based on site-specific, risk-based cleanup criteria. EPA has issued risk-based clean closure guidance (USEPA, March 1998). This guidance confirms that, under current regulations, RCRA-regulated units may be clean closed to protective, risk-based cleanup levels. All hazardous waste must still be removed but hazardous constituents can remain as long as they are protective of both human health and the environment. A copy of the EPA risk-based clean closure guidance is included in Appendix J.4 and a summary discussion in Sect. 2.1.1.2.

There are several advantages to a risk-based approach for establishing cleanup target levels. First, risk assessment provides a scientifically defensible and increasingly accepted method for establishing cleanup levels that are protective of human health and the environment, considering site-specific factors. In contrast, the use of generic criteria (which are often not risk-based or developed based on assumptions that are not appropriate to the site being evaluated) may yield cleanup levels that are either not sufficiently protective, or are overly stringent and wasteful of limited resources for a particular site. However, these generic criteria are frequently used for screening assessments to determine if a risk assessment is warranted (i.e., if the generic criteria are considered appropriate for the site and there are no exceedances of the criteria and/or natural background).

Risk based cleanup levels are usually developed using the basic methodologies and assumptions applied in the risk assessment. Often, cleanup levels are "back-calculated" to correspond to an overall risk goal for a site. This is achieved by setting chemical-specific cleanup levels equal to chemical concentrations believed to have no adverse effect on human health or the environment and that pose an "acceptable" or "insignificant" cancer risk.

In many instances, the methodologies and assumptions used in the forward calculation of risk in the risk assessment will also be used in a backward calculation of cleanup goals. Thus, establishing proper assumptions (i.e., not overly conservative) used during the baseline risk assessment is critical to ensure that, if remediation is necessary, these assumptions will guide proper development of appropriate cleanup goals.

The goal of risk-based clean closure is to ensure protection of human health and the environment. Therefore, both human health and ecological effects must be considered separately within the risk-based clean closure framework. Sects. 8.1 and 8.2 provide an overview of the baseline risk assessment process (with guidance resources cited) for human health and ecological, respectively.

However, the lead regulatory agency should be contacted to determine site-specific requirements for clean closure and to negotiate assumptions to be used for the conduct of risk assessments if risk-based closure is selected.

The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) has risk assessment experts in many related fields and, as the representative arm of the Army Surgeon General, has the role of reviewing and approving all Army human health and ecological risk assessments (AR 200-1, Sections 1-18 & 11-9). USACHPPM, therefore, is an important technical resource for the development and implementation of risk areas.

8.1 HUMAN HEALTH RISK ASSESSMENT PROCESS

The human health risk assessment process involves the following components:

- Data evaluation,
- Exposure assessment and toxicity assessment,
- Risk characterization, and
- Uncertainty assessment.

The primary purpose of the data evaluation task is planning, scoping, and problem formulation as well as identifying and selecting constituents that are representative of the type and magnitude of potential human health effects. As discussed in Sect. 7, this should be based on site investigation data and screening results.

In the exposure assessment, a conceptual site model should be developed to define the exposure setting. Potential exposures either at the source area or offsite should be identified. Exposure routes should be developed from information regarding source area concentrations, chemical release mechanisms, patterns of receptor activity (under both current and potential future land use patterns), and other pertinent information. Equations and exposure assumptions should be used to calculate "acceptable" exposure concentrations.

The toxicity assessment should present the available data used to define the potential for the constituents to cause adverse effects. Reference doses (RfDs) and cancer slope factors (CSFs) should be provided for oral, inhalation, and dermal exposures.

Toxicological information needed for the human health risk assessment should be based on readily available references such as the following (listed in order of priority):

- EPA Integrated Risk Information Systems (IRIS), (http://www.epa.gov/iris/)

- EPA Health Effects Assessment Summary Tables and other information from the National Center for Environmental Assessments (HEAST), (http://www.epa.gov/ncea/)

- EPA Criteria Documents (e.g., Health Advisories and Drinking Water Criteria Documents), http://www.epa.gov/ost/drinking/standards/

- Agency for Toxic Substances and Disease Registry (ASTSDR) Toxicity Profiles (http://www.atsdr.cdc.gov/atsdrhome.html)

- Registry of Toxic Effects of Chemical Substances (RTECS) (http://www.cdc.gov/niosh/rtecs.html)

- National Institute of Occupational Safety and Health (NIOSH) (http://www.cdc.gov/niosh/homepage.html)

The risk characterization assessment should be used to develop risk-based cleanup criteria considering the combined impact from multiple constituents and potential land use of the OB/OD unit.

The final portion of the risk assessment is the uncertainty evaluation. Varying degrees of uncertainty are associated with each step of the risk assessment. This involves a brief evaluation of the site-specific and general assumptions concerning exposure and toxicity that can lead to uncertainties in the estimation of risk-based cleanup goals.

EPA has developed guidance for the conduct of human health risk assessments. Standard EPA guidance includes the following:

- Risk Assessment Guidance for Superfund (RAGS). This includes multiple documents (as well as associated tools and other technical resources) and updates as identified at the EPA Superfund Risk Assessment web page (http://www.epa.gov/superfund/programs/risk/toolthh.htm)

- Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (USEPA July 1998 draft and subsequent revisions/updates). This RCRA guidance (and updates) are available at the EPA Region 6 web page (http://www.epa.gov/earth1r6/6pd/rcra_c/protocol/protoco.htm)

- Application of EPA media specific and integrated multimedia models to evaluate the potential for contamination migration (http://www.epa.gov/epahome/Data.html)

Some regulatory agencies may allow for a tiered approach for the conduct of human health risk assessments, such as the one outlined in Standard Guide to Corrective Action at Petroleum Release Sites (ASTM, 1995). The American Society for Testing and Materials (ASTM) tiered approach, commonly known as Risk-Based Corrective Action (RBCA), consists of three tiers of risk evaluation to determine a cost-effective and protective site remedy. Issues that affect the scope of the risk evaluation, such as land and groundwater use, should be addressed in Tier 1 or Tier 2 of the RBCA process. However, site-specific data and refined exposure modeling are not typically incorporated until a higher tier (e.g., Tier 3) of a RBCA process.

As previously recommended, USACHPPM and the lead regulatory agency should be contracted to establish the protocol for the human health risk assessment protocol.

8.2 ECOLOGICAL RISK ASSESSMENT PROCESS

EPA defines ecological risk assessment (ERA) as a process that evaluates the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors. In the context of the Superfund Program under CERCLA, ERA is defined as a qualitative and/or quantitative appraisal of the actual or potential impacts of contaminants from a hazardous waste site on plants or animals other than humans and domesticated species. ERAs prepared in the context of RCRA, including ERAs for closure of OB and OD units, may be defined similarly. The need for ERAs stems from the fact that CERCLA and RCRA authorize EPA to protect public health and welfare *and the environment* from the release or potential release of any hazardous substance, pollutant, or contaminant.

ERAs prepared under CERCLA and RCRA usually assess the effects of exposure of natural plant and animal populations (ecological receptors) to chemical contaminants (stressors). ERAs do not consider effects on humans, domesticated livestock, or crops. ERAs are conceptually similar to human health risk assessments but are directed toward protecting the environment, specifically natural communities of terrestrial and aquatic biota.

8.2.1 General ERA Guidance

EPA published the following guidance document outlining a general approach for performing ERAs:

> USEPA (U.S. Environmental Protection Agency). 1998. *Guidelines for Ecological Risk Assessment*. EPA/630/R-95/002F. April 1998, Final. Download at http://www.epa.gov/ncea/ecorsk.htm

The document defines terms such as risk, stressors, receptors, endpoints, and exposure pathways in the context of ecological risk assessment. It presents the five components to any ERA shown in Table 8.2-1. It discusses the ERA process in a broad context not limited to situations in which the stressors are chemical contaminants. Examples of other possible ecological stressors (not usually considered in the context of CERCLA or RCRA) include habitat alteration, fire, or the introduction of predators or pests.

8.2.2 ERA Guidance for Superfund

EPA published the following guidance for preparing ERAs for hazardous waste sites investigated under the Superfund Program (CERCLA):

> USEPA (U.S. Environmental Protection Agency). 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments*. EPA/540/R-97/006. June 5, 1997, Interim Final. Download at
> http://www.epa.gov/oerrpage/superfund/programs/risk/ecorisk/ecorisk.htm

Table 8-1. Summary framework for ecological risk assessment

Planning	Careful planning is essential when initiating an ERA and throughout the ERA process. Planning is necessary to define the scope of the ERA and the specific efforts needed to accomplish that scope. In the initial planning, the management goals and objectives of the ERA must be determined. The focus of the ERA must be laid out, and a timeframe for completing the assessment must be projected.
Problem Formulation	Problem formulation is an extension of planning. It involves identifying stressors (harmful substances, conditions, or actions), receptors (plants, animals, and/or ecosystems potentially subject to adverse effects), and pathways by which receptors may be exposed to stressors. These pathways can then be illustrated in a conceptual site model. The conceptual site model is used to identify assessment endpoints, the ecological values that will serve as the focus of the ERA.
Analysis	Analysis involves data collection, technical evaluation of the data, and calculation of existing and potential exposures and ecological effects at the site.
Risk Characterization	Risk characterization involves using the results of the analysis to draw risk conclusions. The likelihood and severity of the risk is related back to the assessment endpoints identified in problem formulation. An important element of risk characterization is identifying the uncertainty associated with the conclusions drawn.
Risk Management	Risk management involves integrating the results and conclusions from the ERA with other considerations to make and justify remedial decisions.

This document is sometimes referred to as *Ecological Risk Assessment Guidance for Superfund* (ERAGS). It outlines the eight steps for completing the ERA process shown in Table 8.2-2. The process involves completing the steps in a phased sequence punctuated by frequent scientific/management decision points (SMDPs) where the investigative effort can be continued, terminated, or redirected. Each step involves increasingly rigorous investigation. The process is terminated whenever completion of a step satisfactorily demonstrates that there is no potential for ecological risk.

The results of the first two ERAGS steps are typically reported in a **Screening ERA**. Ecological screening uses limited data (typically general site observations, published literature, and previously published site data) and conservative assumptions to evaluate whether there is a realistic probability of significant ecological risk. The ERA process terminates if screening reveals little or no potential ecological risk. Otherwise, the investigation continues to the later ERAGS steps. The results from those later steps are typically reported in a **Baseline ERA**. Rather than relying on conservative assumptions, a Baseline ERA must be supported with site-specific data. If adequate site-specific data do not already exist, they must be obtained through quantitative site investigation, sampling, laboratory tests, or other sources. The scope of Baseline ERAs is highly variable, depending on site complexity and the extent of earlier investigations.

Most government agencies follow ERAGS when preparing ERAs for sites with chemical contamination, whether in the context of CERCLA or RCRA. The U.S. Army, Navy, and Air Force have jointly published the following guidance document that summarizes ERAGS for the purpose of contaminated sites on military bases:

> Simini, M., R. T. Checkai, and M. E. Ellen. 2000. *Tri-Service Remedial Project Manager's Handbook for Ecological Risk Assessment*. SFIM-AEC-ER-CR-200015. February 24, 2000. Download at http://chppm-www.apgea.army.mil/erawg/products.htm.

This document closely parallels ERAGS but emphasizes efficiency and the importance of terminating investigation as soon as the absence of significant ecological risk can be reasonably demonstrated. It refers to the Screening ERA as a **Tier 1 ERA** and the Baseline ERA as a **Tier 2 ERA**. If an initial Baseline ERA must be expanded to report further investigation, the expanded document is referred to as a **Tier 3 ERA**.

8.2.3 Initial ERA Planning

Careful planning is essential to the ERA process. Each EPA Region has established a Biological Technical Review Group (BTAG) whose function is to provide technical advice on the ERA process. Guidance on the availability and use of BTAGs is provided in:

> USEPA (U.S. Environmental Protection Agency). 1991. *The Role of BTAGs in Ecological Assessment*. ECO Update 1(1), September 1991. Publication 9345.0-051. Download at http://www.epa.gov/superfund/programs/risk/ecoup/

Table 8-2. Eight-step ecological risk assessment process for Superfund

Step	Description
1	Screening Level: • Site Visit • Problem Formulation • Toxicity Evaluation
2	Screening Level: • Exposure Estimate • Risk Calculation
3	Problem Formulation • Toxicity Evaluation • Assessment Endpoints • Conceptual Model/Exposure Pathways • Questions/Hypotheses
4	Study Design and Data Quality Objective Process • Lines of Evidence • Measurement Endpoints • Work Plan and Sampling and Analysis Plan
5	Verification of Field Sampling Design
6	Site Investigation and Data Analysis
7	Risk Characterization
8	Risk Management

Adapted from Exhibit I-2 of:

USEPA (U.S. Environmental Protection Agency). 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments*. EPA/540/R-97/006. June 5, 1997, Interim Final

The BTAG will assist in designing a scope for a Screening (Tier 1) ERA tailored specifically to the individual site. Initiation of a Screening ERA without first consulting the BTAG is not recommended. Once the Screening ERA is drafted, the BTAG will provide comments and assist in designing a Baseline ERA, if determined to be necessary.

It is critical that the BTAG be consulted before development of workplans for environmental sampling. As is true for the human health risk assessor, the ecological risk assessor must be involved in designing the sampling program. Until recently, many ERAs were planned only after extensive sampling programs had been completed. Ecological risk assessors were forced to work with data developed primarily to address human health issues or request remobilization for supplementary sampling.

At the initial meeting, it will be necessary to thoroughly brief the BTAG concerning the setting, history, and ecology of the site. EPA has prepared the following general guidance on what information is needed by the BTAG:

> USEPA (U.S. Environmental Protection Agency). 1992. *Briefing the BTAG: Initial Description of the Setting, History, and Ecology of a Site*. ECO Update 1(5), September 1992. Publication 9345.0-051. Download at http://www.epa.gov/superfund/programs/risk/ecoup/

At a minimum, the briefing should include a map of the site, a sketch showing the general location of each natural habitat on the site, information on the land use history of the site and surrounding areas, and a list of chemical constituents known to occur or potentially occur on the site.

Subsequent meetings with the BTAG are recommended at each SMDP in the ERA process. Frequent interim coordination with the BTAG; in the form of phone calls, faxes, or short letters; is recommended.

8.2.4 Screening ERA

Screening ERAs are desktop investigations using published data and conservative assumptions to determine whether the potential for ecological risk is great enough to warrant further investigation. ERAGS directs that one of three possible conclusions be drawn from a Screening ERA:

1. There is adequate information to conclude that ecological risks are negligible and therefore no need for remediation on the basis of ecological risk; or

2. The information is not adequate to make a decision at this point, and the ERA process will continue; or

3. The information indicates a potential for adverse ecological effects, and a more thorough assessment is warranted.

Conclusion (1) terminates the ERA process. Conclusions (2) or (3) indicate a need to proceed to a Baseline ERA. The scope of that Baseline ERA may be narrow or broad. Cleanup goals cannot be established on the basis of information from a Screening ERA.

For sites with only one or a few chemical constituents under investigation, the Screening ERA is usually short. For sites investigated for numerous chemical constituents, the Screening ERA usually serves to narrow the list of constituents that must be considered in a Baseline ERA. Chemical constituents not eliminated from the ERA process by screening are sometimes referred to as **ecological contaminants of concern** (COCs).

General Procedures: EPA has published the following general guidance for preparing Screening ERAs for Hazardous Waste Combustion Facilities:

> USEPA (U.S. Environmental Protection Agency). 1999. *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities.* Office of Solid Waste. Peer Review Draft, August 1999. EPA530-D-99-001A. Download at http://www.epa.gov/epaoswer/hazwaste/combust/ecorisk.htm

The U.S. Army Center for Health Promotion and Preventative Medicine has also prepared similar draft guidance on conducting screening ERAs:

> U.S. Army Center for Health Promotion and Preventative Medicine, 2000. Draft Standard Screening-level Measures of Ecotoxicological Effects Revision 3.1 October 2000. U.S. Army Environmental Center, Aberdeen, Maryland.

This draft guidance is provided in Appendix J.13.

General guidance on Screening ERAs has also been issued by several EPA regions. The BTAG should also be consulted for specific direction on ecological screening for each site.

The ecological site description used to brief the BTAG should be included in the problem formulation component of Screening ERA reports. The problem formulation component should also include a **conceptual site model** identifying pathways by which each group of ecological receptors might be exposed to chemical constituents in each medium on the site. The conceptual site model should identify **assessment endpoints**, environmental values that are to be protected by the ERA process. For Screening ERAs, assessment endpoints are usually defined very broadly (for example, protection of the most sensitive ecological receptors affected by specific exposure pathways).

Risk characterization in Screening ERAs typically involves calculating **hazard quotients** (HQs) using two procedures:

1. Comparing concentrations of chemicals in environmental media at the site against media-specific benchmark concentrations (screening values) shown in the scientific literature to pose minimal risk to ecological receptors, and

2. Comparing doses of chemicals in the diets of ecological receptors against benchmark doses shown in the scientific literature to pose minimal risk to ecological receptors.

The comparisons against screening values is best suited to addressing potential risk to receptors directly inhabiting soil, sediment, or water. The comparisons against benchmark doses are best suited to addressing potential risk to wildlife and birds exposed to the chemicals primarily though diet. Estimating exposure through diet is usually termed **food chain modeling**.

HQs are calculated by dividing the measured concentration of a constituent in a medium (for example, surface soil) against the corresponding benchmark concentration, or by dividing the estimated dose of a constituent in the diet of a specific receptor species (for example, deer mouse), by the corresponding benchmark. An HQ less than 1.0 can usually be interpreted as indicating little potential for ecological risk. An HQ greater than or equal to 1.0 is usually interpreted as indicating that further investigation is needed to determine whether ecological risk exists. The magnitude of an HQ that exceeds 1.0 is not customarily interpreted as indicating the relative severity of potential ecological risk.

Hazard indices (HIs) are rarely calculated in ERAs. For groups of chemical constituents with very similar toxicological mechanisms, an HI may be calculated by summing the HQs for each individual constituent. The interpretation of an HI is similar to that for an HQ and accounts for possible additive effects from multiple constituents. Receive specific direction from the BTAG before using HIs in an ERA.

Media-Specific Screening: The BTAG should always be consulted concerning which screening values are most appropriate for a given site. Several alternative sets of screening values are available, and selection of appropriate screening values for any given site, requires professional judgement on the part of the ecological risk assessor and BTAG. Many EPA regions have independently published lists of screening values appropriate for most sites in their regions. Some examples include:

USEPA (U.S. Environmental Protection Agency). 1995. *Revised Region III BTAG Screening Levels*. USEPA Region 3, Philadelphia, Pennsylvania, August 9, 1995. Not available for download.

USEPA (U.S. Environmental Protection Agency, Region IV). 1998. *Ecological Risk Assessment at Military Bases: Process Considerations, Timing of Activities, and Inclusion of Stakeholders*. USEPA, Region 4, Atlanta, Georgia, December 22, 1998. Not available for download.

EPA regional lists of screening values usually provide separate values for soil, sediment, and surface water. The values generally correspond to the highest chemical concentration known not to adversely affect the more sensitive species potentially inhabiting the indicated medium. Some lists (e.g., the EPA Region 3 list) provide separate sets of screening values for different groups of ecological receptors, such as plant and animal receptors. Others merely provide a single set for all possible ecological receptors.

Some EPA regions have not developed regional lists of screening values. The EPA has produced a national list, termed Ecotox thresholds (ETs). ETs and guidance on their use are provided in:

> USEPA (U.S. Environmental Protection Agency). 1996. *Ecotox Thresholds*. ECO Update 3(2), January 1996. Publication 9345.0-12FSI. Download at http://www.epa.gov/oerrpage/superfund/resources/ecotox/eco_updt.pdf

Where EPA has developed National Ambient Water Quality Criteria (NAWQC) for protection of aquatic biota, these criteria may be used as media-specific screening values for biota inhabiting surface water. NAWQC are established through regulation. They are initially proposed in the *Federal Register* and, upon adoption, codified in the *Code of Federal Regulations*. Certain states have also legislated water quality criteria in the same way that NAWQC have been established federally. When available, NAWQC and state equivalents are Applicable, Relevent, and Appropriate Regulations (ARARs) under CERCLA and should be considered in addition to other screening values that may be used. Only NAWQC values for chronic effect should be used as screening values, and the NAWQC values for the appropriate habitat (freshwater or marine) should be used. If only a NAWQC for acute effects is available, it should be considered but other more conservative screening values should also be considered.

EPA has also developed Tier II criteria for certain contaminants in surface water for which NAWQC values have not yet been developed through regulation. A good review of NAWQC and Tier II Values is provided in:

> Suter, G.W. and C. L. Tsao. 1996. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision*. ES/ER/TM-96.R2. U.S. Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

The Oak Ridge National Laboratory (ORNL) has developed an extensive list of screening values (termed benchmarks) for use in ERAs on the U.S. Department of Energy (DOE) Oak Ridge Reservation in Tennessee. These benchmarks have been widely used for non-DOE sites as well, but like all benchmarks should not be used without BTAG concurrence. ORNL provides separate sets of benchmarks for plants, soil and litter invertebrates, sediment-dwelling biota, aquatic biota, and terrestrial wildlife. The ORNL benchmark publications may be downloaded from http://www.hsrd.ornl.gov/ecorisk/reports.html.

BTAGs usually recommend that a single, preferred source of screening values be used.

But no single set of source includes values for every possible chemical in every medium. It may be necessary to consult alternate sources to find screening values for certain chemicals in certain media. If suitable screening values are not available from any published list, it may be possible to derive suitable values using data in journal articles, textbooks, or other ecotoxicological literature. If it is impossible to find or derive an appropriate screening value for a given chemical/medium combination, the BTAG may recommend investigating that combination in a Baseline ERA.

BTAGs generally recommend against using background concentrations, even site background values, as screening values. Screening values should have a strictly ecotoxicological basis. Elimination of ecological COCs based on background conditions is usually deferred to the risk management component of a Baseline ERA.

Dose Screening: BTAGs differ on whether dose screening, which requires food chain modeling, should be included in a Screening ERA. Some BTAGs consider dose screening to be the only way to determine whether certain ecological receptors (especially wildlife, birds, and fish) may be at significant risk via exposure to contamination via diet. Other BTAGs consider most published screening values to be highly conservative and do not recommend expending effort to calculate dietary exposure for a large number of chemical constituents. Some BTAGs might recommend food chain modeling and dose estimation at the screening stage only for certain chemical constituents known to have a high likelihood of accumulating in receptor tissues at harmful concentrations.

Food chains involve a hierarchical arrangement of **predators**, species that feed on the tissues of other species, and **prey**, the species serving as the food. Most food chains involve multiple levels where the predators from one level function as the prey at the next level. The levels in a food chain are termed **trophic levels**. Food chain modeling involves using chemical concentrations in soil, water, and other media to calculate estimated concentrations in the tissues of prey organisms inhabiting or ingesting those media. It then uses estimated concentrations in the prey tissues to calculate doses to predators. The calculation procedure can be continued through multiple trophic levels.

Food chain modeling requires information on the body weight of ecological receptors, food and water ingestion rates for receptors, and multiplication factors (termed **uptake factors** or **bioconcentration factors**) used to estimate chemical concentrations in prey tissue based on known concentrations in environmental media. EPA's *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (1999), cited above, provides summary tables of body weights and ingestion rates for several species of wildlife and birds.

Another publication with body weight and ingestion rate data is:

McVey, M., K. Hall, P. Trenham, A. Soast, L. Frymier, and A. Hirst. 1993. *Wildlife Exposure Factors Handbook*. U.S. Environmental Protection Agency, Washington, D.C., December 1993. EPA/600/R-93/187a. Not available for download.

Other summaries of body weight and ingestion rate data are available, and data may be obtained directly from primary literature. The BTAG may also be able to suggest other sources of data.

EPA's *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (1999) also provides uptake factor data (termed as bioconcentration factors). Several publications outlining uptake factors for various media and tissue combinations have been developed by ORNL. They may be downloaded from http://www.hsrd.ornl.gov/ecorisk/guidance.html. The BTAG may be able to suggest other sources of uptake factors. Uptake factor data are highly limited for many commonly investigated data. In the absence of uptake factor data, uptake factors of 1.0 are sometimes used as conservative estimates.

Once doses are estimated using food chain modeling, HQs may be calculated by comparing doses against benchmark doses reported in the scientific literature to not result in adverse impacts to ecological receptors. The highest dose reported to not result in adverse impacts is termed the **No Observed Adverse Effects Level** (NOAEL). The smallest dose reported to result in adverse effects is termed the **Lowest Observed Adverse Effects Level** (LOAEL). Only NOAELs are acceptable for use in Screening ERAs. If a LOAEL is reported without a corresponding NOAEL, the NOAEL may be conservatively estimated by multiplying the LOAEL by 0.1.

EPA's *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (1999) provides summary tables of NOAELs and LOAELs for several species of wildlife and birds. Another set of NOAEL and LOAEL tables is provided in:

> Sample, B.E., D.M. Opresko, and G.W Suter II. 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision.* U.S. Department of Energy, Office of Environmental Management, Oak Ridge Tennessee. ES/ER/TM-86/R3. Download at http://www.hsrd.ornl.gov/ecorisk/tm86r3.pdf

NOAELs may also be developed based on primary scientific literature, and the BTAG may be able to offer assistance on sources of NOAEL data. The BTAG can also offer guidance on estimating NOAELs from primary literature reporting ecotoxicological information using various other measures such as lethal dose 50 (LD50).

8.2.5 Baseline ERA

The breadth of scope for Baseline ERAs is much more variable than for Screening ERAs. The objective of any Baseline ERA is to eliminate uncertainty regarding the potential risk to ecological receptors. Only those chemical constituents and exposure pathways not eliminated as representing potential ecological risk by the Screening ERA are carried forth into the Baseline ERA. As with other ERA efforts, a Baseline ERA should not be initiated without consulting the BTAG.

Most Baseline ERAs begin with a refinement of the conceptual site model developed for the Screening ERA. Assessment endpoints must be defined more specifically. That sometimes requires completion of one or more preliminary investigations in coordination with the BTAG. Sometimes more detailed ecological field surveys must be conducted to better identify the specific ecological receptors potentially affected by the site. Sometimes an expanded program of environmental media sampling is needed. If an initial round of food chain modeling using conservative assumptions was not performed as part of the Screening ERA, the BTAG may recommend that it be performed in the initial stages of a Baseline ERA.

The primary focus of most Baseline ERAs involves collecting additional site-specific data allowing for refinement of the conservative assumptions underlying the screening values, uptake factors, and benchmark doses used in the Screening ERA. Some examples of types of investigations that might achieve that purpose include:

- Toxicity tests to determine whether test organisms are adversely affected by media contaminated with higher concentrations of a chemical than published screening values,

- Toxicity tests to determine whether test organisms are adversely affected by doses greater than published NOAELs,

- Uptake tests to determine whether prey tissue bioaccumulates chemicals from environmental media at ratios less than published uptake factors, and

- Sampling and laboratory analysis of prey tissue (especially plant and earthworm tissue) to validate whether concentrations estimated using uptake factors may be adjusted.

Data from the types of studies listed above may be used to refine the food chain modeling to eliminate some or all COCs not eliminated by screening.

Baseline ERAs may also include comparison of the numbers and diversity of ecological receptors at contaminated sites against uncontaminated reference sites. Such comparisons are especially common for benthic macroinvertebrate communities in streams.

8.2.6 Risk Management

Risk management uses the results of the Baseline ERA to make decisions concerning appropriate remedies for a site. While the Screening ERA and Baseline ERA focus narrowly on ecotoxicological investigation, risk management is broadly integrated into the overall planning process for cleaning up and closing the site. The findings of the Baseline ERA and human health risk assessment are jointly used to develop preliminary remediation goals (PRGs) for the site.

It is very important that the benchmarks used in the Screening ERA (media-specific screening values and NOAEL-based dose levels) are not used as the basis for developing PRGs. One exceptions is the series of NAWQC and other water quality criteria established through regulation. Most screening benchmarks were developed using conservative assumptions solely for the purpose of identifying chemicals that clearly do not require rigorous investigation. It is rarely necessary to clean up a site to the degree reflected by the conservative assumptions used in screening.

PRGs are generally developed based on the results of the Baseline ERA. A number of practical considerations excluded from the ecotoxicological focus of the Screening and Baseline ERAs may be considered during risk management and PRG development. Some examples of such practical considerations include:

- Not developing PRGs lower (stricter) than background concentrations (especially for metals and other substances that occur naturally in uncontaminated environments),

- Consideration of LOAEL-based PRGs instead of stricter goals based on NOAELs,

- Considering whether the costs to implement stricter PRGs are justified considering the ecological value of the protected receptors, and

- Considering whether the ecological impacts from the implementation of cleanup efforts (e.g., the effects of physically disturbing sensitive natural areas) outweigh the ecological benefits of protecting the affected receptors.

As is true at other stages of an ERA, BTAG consultation is a very important component of risk management. Because PRGs must be developed to address human health as well as ecological risk, risk management must be jointly conducted with the involvement of experts contributing to both risk assessments.

9. CLOSURE PLAN CONTENT

The minimum content requirements of a closure plan are identified in 40 CFR 264.112(b) and 265.112(b), "Content of Plan." This section of the guidance contains a detailed discussion of these requirements. This information should also be provided in alternative enforceable documents if corrective action or an alternative closure process is used. A summary checklist of closure plan requirements for Subpart X units is provided in Appendix A based on EPA guidance (USEPA, March 1992).

Although not specifically stated in 264/265.112(b), all closure plans should include the following additional information that enables the regulator to understand the complete closure process (see Fig. 9-1):

- Background information such as facility location and unit description (see Sect. 5);
- Investigative techniques such as soil sampling and groundwater monitoring (see Sect. 6);
- Data analysis including definition of statistically significant above background (see Sect. 7); and
- The risk assessment including the closure performance standards (see Sect. 8).
- 40 CFR 264/265.112 (b) requirements (as discussed in this section).

The minimum content requirements pursuant to 40 CFR 264/265.112(b) of a closure plan are summarized below (see Fig. 9-2). Except where noted, the "content of plan" for permitted facilities [40 CFR 264.112(b)] and facilities operating under interim status [40 CFR 265.112(b] are the same. These requirements are:

- A description of how each hazardous waste management unit at the facility will be closed in accordance with the closure performance standard [40 CFR 264/265.112(b)(1)];
- A description of how final closure of the facility will be conducted in accordance with the closure performance standard, to include the maximum extent of the operations which will be unclosed during the active life of the facility [40 CFR 264/265.112(b)(2)];
- An estimate of the maximum inventory of hazardous wastes ever onsite over the active life of the facility and a detailed description of the methods for removing and managing all hazardous wastes (including identification of the type(s) of the offsite hazardous waste management units to be used, if applicable) [40 CFR 264/265.112(b)(3)];

- A detailed description of the steps needed to remove or decontaminate all hazardous waste residues and contaminated containment system components, equipment, structures, and soils (including procedures for cleaning equipment and removing contaminated soils, methods for sampling and testing surrounding soils, and criteria for determining the extent of decontamination required to satisfy the closure performance standard) [40 CFR 264/265.112(b)(4)];

- A detailed description of other activities necessary to satisfy the closure performance standards (including groundwater monitoring, leachate collection, and run-on and run-off control) [40 CFR 264/265.112(b)(5)]; and

- A closure schedule for each hazardous waste management unit [40 CFR 264/265.112(b)(6)].

Closure plans at interim status facilities that have not been approved (see Sect. 4) must also contain the estimated year of final closure [40 CFR 265.112(b)(7)].

In addition, closure plans for OB/OD units that plan to clean close should contain:

- A contingent closure plan [40 CFR 264/265.112(a)], and

- A post-closure plan (40 CFR 264/265.118) if there is the potential that clean closure may not be achieved (i.e., this is expected to apply to risk-based closures) pursuant to the EPA Subpart X permit writers' guide (USEPA, June 1997).

Closure plans with clean closure performance standards must include a contingent closure plan as a discrete component that describes how closure will be performed in case clean closure cannot be achieved. Also, in the event that the contingent closure plan must be implemented, post-closure care must be performed. Therefore, closure plans should also contain a post-closure plan and a section on required notices for land disposal facilities. These requirements are also discussed in this section of the guidance.

State and EPA Regional offices should be contacted to confirm the required contents of the closure plan.

9.1 UNIT AND FACILITY CLOSURE

The closure plan should fulfill the regulatory requirements of both 40 CFR 264/265.112(b)(1) and (2). The first citation requires a description of how each hazardous waste management unit at the facility will be closed in accordance with the closure performance standard. The last citation requires a description of how final closure of the facility will be conducted in accordance with the closure performance standard, including the maximum extent of the operations which will be unclosed during the active life of the facility. These requirements are summarized in Fig. 9-3.

9.1.1 Closure in Accordance with Closure Performance Standard

The closure plan should also describe the overall approach for achieving the closure performance standard (clean closure, including risk-based clean closure or closure with waste in place). This discussion should link the closure performance standard section of the closure plan (described in Sect. 8) to the actual steps conducted to achieve the standard (described below). Soil removal and groundwater remediation should only be referenced in this section of the closure plan as methods to achieve the standard; the actual steps should be described in detail in subsequent sections of the closure plan.

9.1.1.1 Clean Closure

If the goal of the closure plan is clean closure (including risk-based clean closure), this section of the plan must briefly restate the clean closure performance standard. That is, in order for the site to be considered clean closed, CPCs must not exist in concentrations that pose a risk to human health and the environment.

In cases where site-specific risk-based values meet the clean closure standard, the closure plan should state that cleanup action for soil and groundwater will not be necessary. In these cases, the closure plan should state that the results of the risk assessment will be the basis for documenting clean closure. However, proper management of other wastes (i.e., other than contaminated environmental media) generated during closure as well as decontamination of equipment utilized during closure must be accomplished. Therefore, the closure plan needs to describe these waste management procedures.

In cases where site-specific risk-based values do not meet the clean closure standard, the closure plan should state that cleanup action for soil and groundwater will be necessary. Note that this section of the closure plan need only introduce the remediation approach to be taken; the step-by-step procedures should be described later in the plan.

9.1.1.2 Closure With Waste in Place

If the goal of the closure plan is closure with waste in place, this section must briefly restate the landfill closure performance standard, which is that the hazardous wastes that are left in place, due to structures installed during closure, will not pose a significant risk to human health and the environment. Note that this section of the closure plan need only introduce the structures to be installed (e.g., capping and run-off controls); the detailed description of these structures should be described later in the plan (see discussion below).

9.1.2 Maximum Extent of Operations Unclosed During Active Life of Facility

The closure plan should also describe the maximum extent of the operations which will be unclosed during the active life of the facility, which is the period from the initial receipt of hazardous waste until the regulator receives certification of final closure.

The purpose of this estimate is to indicate the largest area that would need to be closed if the facility were forced to close unexpectedly. At some facilities, the estimate of the maximum extent of operations is equivalent to maximum design capacity. This is almost always the case at OB and OD units.

9.2 MAXIMUM HAZARDOUS WASTE INVENTORY AND WASTE MANAGEMENT METHODS

The closure plan must include a section defining the maximum waste inventory and waste management methods to be used for closure (see Fig. 9-4).

9.2.1 Maximum Hazardous Waste Inventory

The closure plan must include an estimate of the maximum inventory, including all undisposed hazardous wastes and residues, ever onsite at any time over the life of the OB and OD units.

At an OB unit, the maximum amount of inventory should include:

- The maximum amount of energetic materials that could be left awaiting treatment at the unit, and
- the maximum amount of ash generated from OB operations that could be present at the unit.

An OD unit does not have an inventory. To provide a basis for planning how the waste streams generated by OD operations will be managed when the unit closes, this portion of the closure plan should describe the magnitude and duration of OD treatment.

9.2.2 Waste Management Methods

The closure plan must describe the methods of removing, transporting, treating, storing, and/or disposing of all wastes at the unit that may remain at closure and that may be generated in the course of performing closure. These wastes include:

- Unburned reactives,
- UXO,
- Ash (left over and/or generated from burning unreacted materials during closure),
- OB/OD debris (e.g., shrapnel from fragmentation and other waste munition components),
- IDW,
- Decontamination fluids, and
- Environmental media that contain constituents from OB/OD operations.

Specific waste management techniques for the types of wastes identified above are discussed below. In addition, the closure plan should describe general waste management techniques that may apply to any waste discovered during closure. For example, waste containerization and the use of offsite facilities should be addressed in the closure plan. These techniques are described below.

Note that certain waste management requirements may vary among EPA Regions and states; that is, some EPA Regions and states may be more stringent than others in various issues. Some of these policies are summarized in Appendix F and discussed below.

9.2.2.1 Unburned Reactives

Where burn trenches are part of the OB unit design, the plan should state that unburned energetics will be reburned in the trenches. In cases where burn pans are part of the OB unit design and the pans are still present at the unit at the time of closure, the plan should state that unburned energetics will be reburned in the pans. In both cases, the closure plan should state that after reburning, the contents of the trench or pan will be visually inspected to ensure that no unreacted material exists. Any remaining unreacted material will be burned again until it is no longer reactive.

In some cases, the burn pans may have already been removed at the time of closure, and unburned energetic material discovered during closure cannot be reburned onsite. Therefore, the closure plan should describe how any unburned energetic material discovered during closure will be containerized and shipped offsite for treatment and disposal.

Process knowledge or analysis may be used to characterize any unburned energetics. By their nature, these are considered reactive D003 wastes; therefore, the closure plan should state that process knowledge was used to make this determination. Additionally, these wastes may exhibit the characteristic of toxicity due to the presence of metals and/or semivolatile organics. Accordingly, unburned energetics may also be characterized with the waste codes D005 (barium), D007 (chromium), D008 (lead), D011 (silver), D036 (nitrobenzene), D030 (2,4-dinitrotoluene), and D032 (hexachlorobenzene). The closure plan should state whether process knowledge or analysis was used in evaluating the waste for TCs.

The closure plan should also state that unburned energetics determined to be hazardous wastes will be manifested in accordance with RCRA Subtitle C regulations, and that the appropriate LDR notification will accompany the waste shipment.

9.2.2.2 UXO

For OD units, the closure plan should state that UXO discovered during closure will be detonated in place based on safety considerations. If the UXO is an item normally not treated at the unit (e.g., a chemical agent or smoke), subsequent management will depend on its stability. Generally, unfuzed ammunition and items are considered to be stable, whereas fuzed items are considered unstable, as they may have internally damaged components. Unstable nonconventional rounds should be treated in place by qualified EOD personnel under the RCRA emergency treatment provision. Depending on the state, an emergency permit may be required. If practicable, stable nonconventional rounds should be transported to an area designated for this type of treatment.

For OB units, management of any UXO item will depend on its stability. If there is an operational OD unit at the installation, stable conventional UXO items should be transported there for safe disposal. Unstable rounds should be treated in place by qualified EOD personnel. If practicable, stable nonconventional rounds should be transported to an area designated for this type of treatment.

Alternative approaches for UXO detection and remediation are summarized in Appendix H and I.

9.2.2.3 Ash

For OB units, RCRA requires that ash be analyzed to determine if it is hazardous. The target constituents should be those that would most likely be present in the ash (TC metals and certain semivolatiles). Therefore, at the time of closure, analysis of any ash that may still be at the site (e.g., in a satellite accumulation area) will already be underway.

Any ash remaining in the burn pans should be collected using brooms and sparkless shovels. For these cases, the closure plan should state that the remaining ash will be managed as hazardous waste until the results of the analysis are final. During this interim period, the ash should remain at the satellite accumulation area. However, if the closure plan calls for the expeditious decontamination of this accumulation area, the ash could be sent elsewhere on post to a generator or permitted/interim status storage unit. Upon receipt of analysis, ash determined to be hazardous waste should be sent to a permitted or interim status treatment facility or landfill. Ash determined to be nonhazardous may be sent to a nonhazardous landfill in accordance with state solid waste regulations.

9.2.2.4 OB/OD Debris

OB/OD debris (e.g., shrapnel from fragmentation and other waste munition components) can be energetic-contaminated or have other hazardous characteristics or constituents. Therefore, these OB/OD debris should be evaluated on a site-specific basis by EOD or UXO trained specialists for appropriate waste characterization and management (UXO management has been discussed in Sect. 9.2.2.2). The management and disposition of OB/OD debris should address the following requirements:

- Explosive safety,
- Demilitarization (trade security), and
- Environmental security.

Therefore, waste management and disposition applicable to range scrap/residue, ammunition, explosives and dangerous articles (AEDA), and disposal of real property are also appropriate for OB/OD debris. Following is a list of some of the major applicable DoD policies:

- DoD 4160.21-M-1, DoD Demilitarization Manual
- DoD 4160.21-M, DoD Material Disposition Manual
- DoD Directive 4165.6, Real Property Acquisition, Management and Disposal
- DoD 6055.9-STD DOD Ammunition and Explosives Safety Standards, Chapter 12 – Real Property Contaminated with Ammunition, Explosives or Chemical Agents.

These and other related DoD policies and directives are available via the DoD Defense Demilitarization and Trade Securities Control web site (http://132.159.221.108/mmd/demil/home.htm). DoD 6055.9-STD is available http://128.174.5.51/denix/Public/ES-Programs/Explosives/Safety/cover.html

Army Regulation 405-90, Disposal of Real Estate, includes requirements for the disposition of contaminated real property (Sect. 2.2). The Army may not transfer accountability of such contaminated property outside of DoD until it is rendered innocuous as defined in Army Regulation 385-64, U.S. Army Explosive Safety Program. These documents are available at the following web page: http://books.army.mil/cgi-bin/bookmgr/Shelves.

USAEC is developing range scrap management guidance to identify and characterize solid waste and residual material generated by military personnel from the intended use (firing and training) of munitions. This effort is being implemented in a phased approach to provide (1) a regulatory analysis of the status of range residues under RCRA and an inventory of munitions items and the associated solid waste and residual material (range residue) generated during training exercises; (2) development of a corporate characterization scheme for residual material and development of characterization profiles for the inventory; and (3) development of Best Management Practices (BMPs) for the inventory, consistent with profiles developed in the characterization phase. This range scrap management guidance will also be useful for the management and disposition of OB/OD debris. Available USAEC guidance is available at the "compliance-munitions management" web site (http://aec.army.mil/prod/usaec/eq/comp/munitions.htm).

9.2.2.5 IDW

Soil and sediment sampling and groundwater monitoring will generate solid and liquid (primarily water) IDW which will require handling and disposal. The closure plan should describe how this waste will be managed. The major types of IDW anticipated include:

- Development water,
- Purge water,
- Drill cuttings,
- Drill rig steam-cleaning fluids,

- Sampling equipment decontamination fluids, and
- PPE.

EPA has developed guidance for the management of IDW and compliance with applicable or relevant and appropriate requirements (ARARs) to the extent possible (USEPA, May 1991).

The most important elements of the IDW management approach are as follows:

- Leaving a site in no worse condition than existed before the investigation.
- Removing those wastes that pose an immediate threat to human health or the environment.
- Leaving onsite wastes that do not require offsite disposal or extended above-ground containerization.
- Complying with Federal ARARs, to the extent practicable.
- Complying with state ARARs, as practicable.
- Careful planning and coordination for IDW management.
- Minimizing the quantity of generated wastes.

The specific elements of the approach are as follows:

- Characterizing IDW through the use of existing information (manifests, Material Safety Data Sheets, previous test results, knowledge of the waste generation process, and other relevant records) and best professional judgment.
- Delineating an AOC unit for leaving RCRA hazardous soil cuttings within the unit.
- Containerizing and disposing of RCRA hazardous groundwater, decontamination fluids, and PPE and DE (if generated in excess of 100 kg/month) at RCRA Subtitle C facilities.
- Leaving onsite RCRA nonhazardous soil cuttings, groundwater, and decontamination fluids preferably without containerization and testing.

State IDW regulatory guidance may also be applicable. It is recommended that IDW requirements should be negotiated with Federal and state regulators before initiation of field work.

The site-specific criteria for characterizing and disposing of IDW should be negotiated with Federal and state regulators before initiation of field work.

9.2.2.6 Non-IDW Decontamination Fluids

The decontamination fluids discussed here are those generated during the closure implementation versus investigation (as discussed above). For example, it may be necessary to decontaminate a hazardous waste satellite storage shed that may exist at an OB/OD unit. In the process, decontamination liquids may be generated. Also, decontamination fluids may be generated during heavy equipment decontamination. The closure plan should state that these liquids should be containerized and analyzed for selected TC metals and semivolatiles. These constituents should be selected based on the characteristics of the waste (usually ash from OB) previously stored in the shed. However, it should not be expected that the decontamination liquids will exhibit a characteristic of a hazardous waste, as the concentration of contaminants is assumed to be small compared to the volume of water used in decontamination.

As with IDW described above, these types of decontamination fluids should be containerized in DOT-approved 55-gal containers or roll-off boxes. During the analysis, these wastes should be managed as if they are hazardous wastes under RCRA Subtitle C. The closure plan should state that IDW determined to be hazardous waste will continue to be managed in accordance with RCRA Subtitle C requirements. Decontamination fluids found to be nonhazardous may either be managed at a RCRA Subtitle D facility, discharged to a publicly owned treatment facility, or left uncontainerized at the site (e.g., pumped onto the ground and allowed to evaporate) depending on the policy of the implementing regulatory agency (see Appendix F).

EPA's contained-in policy should also be used to determine whether these types of decontamination fluids contain a listed hazardous waste (see Appendix F). If the fluids do contain a listed waste, the closure plan should state that they will be managed in accordance with RCRA Subtitle C.

9.2.2.7 Environmental Media with OB/OD Residues

<u>Soil That Contains OB/OD Residues</u>

If it is determined that remediation is necessary, soil removal is usually the remedy. In this case, the soils to be excavated should be sampled and analyzed in order to determine the appropriate method of disposal. The closure plan should state that all soils excavated while analysis is being performed should be containerized and managed as a hazardous waste in a staging area located at or near the unit or at an onsite generator or permitted/interim status storage unit. If any soils exhibit a characteristic of a hazardous waste, they should continue to be managed in accordance with RCRA Subtitle C regulations. Any soils that exhibit a characteristic of hazardous waste should be sent to a RCRA-permitted or interim status facility for treatment (if necessary) and disposal. Otherwise, they may be sent offsite to a RCRA Subtitle D landfill.

In-situ treatment (e.g., bioremediation) may be another alternative. However, the owner/operator should be sure that this will be an effective form of treatment before inclusion in the closure plan. For example, bioremediation may be viable for some soils contaminated with energetics. However, if the soils are also contaminated with metals (a typical scenario for OB/OD units), then soil removal is necessary.

<u>Groundwater That Contains OB/OD Residue Constituents</u>

Based on the analytical results and a statistical analysis, groundwater should be evaluated to determine if it is contaminated. If it is contaminated, it will be treated using an appropriate technology based on the hazardous constituents present and their concentration levels. Usually, contaminated groundwater is treated in-situ through some type of pump and treat operation. Therefore, management of contaminated groundwater is more a remediation issue than a waste management issue. As such, groundwater remediation is discussed below in Sect. 9.3.

9.2.2.8 Waste Containerization

The closure plan should contain a section that describes how wastes will be containerized. Drums to be used for waste containerization should be DOT-approved 55-gal steel drums (drum specification DOT 17-E or DOT 17-H). Before any waste is placed in a drum, a unique identification number should be assigned. Each drum should be labeled with the following information using indelible ink or paint:

- Drum identification number;
- Well identification number (if applicable);
- Type of waste (e.g. drill cuttings, purge water, decontamination fluid contaminated soil, etc.); and
- Date of generation of waste.

9.2.2.9 Use of Offsite Hazardous Waste Management Units

The closure plan should state that, in accordance with 40 CFR 268.7, the owner/operator will ensure that the proper LDR notification accompanies shipments of hazardous waste from the installation, as described below.

In the event that waste exhibits a TC and requires treatment in accordance with the LDR, it should be sent offsite for treatment with the proper manifest and in accordance with LDR requirements. Specifically, as required by 40 CFR 268.7(a)(1), with each shipment of waste the owner/operator must notify the treatment or storage facility in writing of the appropriate treatment standards and prohibition levels. The notification will include the following information:

- EPA Hazardous Waste Number.
- The waste constituents that the treater will monitor, if monitoring will not include all regulated constituents, for wastes F001-F005, F039, D001, D002, and D012-

D043. Generators must also include whether the waste is a nonwastewater or wastewater (as defined in §268.2(d) and (f)), and indicate the subcategory of the waste (such as "D003 reactive cyanide"), if applicable.

- The manifest number associated with the shipment of waste.

If the waste does not meet the treatment standards, no certification is required.

All notifications, waste analysis data, and other relevant documentation should be retained onsite in the facility operating record for at least 5 years. Copies of all manifests must be retained onsite for 3 years after the waste is shipped offsite. If the DOD no longer has a presence on post during the 3- to 5-year period (e.g., if the installation has closed under BRAC), copies of manifests and/or the supporting documentation mentioned above will be transferred to another installation until the 3- to 5-year period has expired.

9.3 CLOSURE PROCESS

The previous section discussed how all wastes generated during closure must be managed. This section addresses how the actual closure process should be described in the plan (see Fig. 9-5).

The closure process will be different depending on whether the unit being closed is an OB unit or an OD unit and, if it is an OB unit, whether it employed pans or trenches. However, closure of most OB/OD units encompasses certain common steps, identified below:

- UXO sweep and disposal,
- Management of non-UXO waste,
- Decontamination of existing structures,
- Soil removal,
- Groundwater remediation,
- Clean closure verification sampling,
- Equipment decontamination,
- Decontamination verification sampling, and
- Followup activities.

9.3.1 UXO Sweep and Disposal

The closure plan should describe how a UXO search will be or was performed. A discussion of the alternative methods for UXO detection and alternative approaches for UXO remediation is presented in Appendix I. For OD units, it should always be assumed that there is a high probability of the presence of UXO. As such, the closure plan should state that the focus of the UXO detection survey will be based on considering the fragmentation boundary as defined in Sect. 3.3.4.

For OB units, although the likelihood of existing UXO may be less, UXO may still be present, especially at installations where munitions have been historically managed. In this case, determining the likelihood of the presence of UXO should be described in the closure plan. This information is readily available for some DOD installations. For example, an Archives Search Report may have been published by the U.S. Army Corps of Engineers which summarizes the presence of UXO at an installation. Such information is based on a compilation of historical research through examination of archives records (including maps and aerial photographs) and interviews with site personnel. If such a report is available, it should be referenced in the closure plan as the basis for characterizing the site for UXO. Otherwise, the closure plan should describe how the owner/operator will compile this information and characterize the site.

If it is determined that UXO is likely to exist at the OB unit, the closure plan should state that the entire OB unit will be swept for UXO by a qualified EOD specialist. If it is determined that no UXO exists at the OB unit, the owner/operator may still want to sweep the area using a magnetometer and clear any metal objects to ensure that the surface and subsurface are clean of UXO. This approach should also be described in the closure plan.

In the event that UXO is discovered, it must be handled accordingly. As such, this section of the plan should reference the waste management section of the closure plan that addresses treatment and disposal of UXO (see Sect. 9.2.2.2 of this guidance).

9.3.2 Management of Non-UXO Waste

Not all closure scenarios will require sorting; therefore, this is an optional step. For example, there may be nothing left to sort at OB units at which the pans are empty at closure. Conversely, there may be high volumes of indistinguishable debris left at OB units that have employed trenches. In this case, an extensive sorting/containerization step would need to be performed. However, in almost all cases, classification, containerization, labeling, storage, and transportation are required.

The closure plan should state that, after it has been determined through either research or the performance of a UXO sweep (and subsequent disposal) that the site is clear of UXO, all other wastes at the site should be classified, sorted (if appropriate), containerized, labeled, and managed accordingly.

Because the specific waste management techniques described in Sect. 9.2 of this guidance should already have been described in the closure plan, this section should only briefly describe these procedures as necessary steps in the closure process. Other appropriate sections of the closure plan should be referenced.

EPA policy guidance regarding the management of remediation waste under RCRA is presented in Appendix J.8 (USEPA, October 1998c).

9.3.2.1 Classification

The closure plan should state that all wastes must first be classified (i.e., identified as hazardous waste, nonhazardous waste, or reusable material). Process knowledge or analysis should be used to determine if the wastes exhibit a TC. EPA's contained-in policy should be used to determine if a waste should carry a hazardous waste listing. Applicable RCRA regulations should be used to determine if a material may be reused or sold as scrap metal.

9.3.2.2 Sorting

After wastes are classified, the closure plan must state that wastes will be sorted according to classification. This may be done in a staging area installed specifically for the closure process; however, the owner/operator may not want to establish a staging area if remediation is not necessary. If a staging area will not be established, sorting may take place at a convenient location near the source of waste. If a staging area will be used, the staging area and the Standard Operating Procedure (SOP) must be described in the closure plan. A typical staging area is described below. A staging area is also described in Sect. 9.3.7 with respect to specific design features for equipment decontamination.

If a staging area is to be used, it should typically consist of a compacted earthen foundation surrounded by 1-ft-high earthen berms. Generally the foundation and berms should be overlain by a 30-mil-thick high-density polyethylene (HDPE) liner of sufficient durability to withstand decontamination activities. Sand or similar material should be spread on top of the liner to prevent tearing. Ramps should be positioned at the entrance and exit of the decontamination pad to allow vehicles to pass over the berms.

Design features that should not be used when constructing staging areas include entrance ways for vehicle entry (contaminated precipitation would escape) and the use of plywood laid on top of the liner in heavy traffic areas (which could cause tearing). The staging area should be partially covered in such a way as to prevent accumulation of rainwater in this area, while allowing work to continue.

Precipitation falling within the bermed area should be managed by designing the bermed area so that it gently slopes to a lined catch basin. Precipitation should be pumped out of the basin, tested, and if nonhazardous disposed of as a nonhazardous waste. If it is hazardous, absorbents should be added and the material treated in the same way as contaminated soil.

9.3.2.3 Containerization and Labeling

The closure plan should state that after wastes are sorted, they are containerized. Roll-off boxes may be used as well as drums. Drums to be used for waste containerization should be DOT-approved 55-gal steel drums (drum specification DOT 17-E or DOT 17-H). Before any waste is placed in a drum, a unique identification number should be assigned and each drum labeled accordingly.

9.3.2.4 Storage

The closure plan should state that after wastes are placed in containers and properly labeled, they are temporarily stored prior to transportation to an onsite or offsite treatment and/or disposal facility. As described above, this may be conducted in a staging area or a RCRA-permitted or interim status storage unit.

9.3.2.5 Transportation

If any materials exhibit a characteristic of a hazardous waste, they will be managed in accordance with RCRA Subtitle C regulations. Any hazardous wastes sent offsite to a RCRA-permitted or interim status facility for treatment (if necessary) and disposal must be properly manifested and be accompanied by the proper LDR notification.

All wastes to be transported offsite must be packaged in containers that meet appropriate DOT shipping and labeling requirements, as specified in 49 CFR 172, 173, 178, and 179. Items classified as hazardous waste must be labeled in accordance with 49 CFR 172.304.

9.3.3 Decontamination of Existing Structures

The closure plan should describe that after all existing wastes are removed from the site, any existing structures will be decontaminated. Structures that are likely to exist at the time of closure include burn pans and hazardous waste accumulation areas (e.g., sheds, etc.).

Example guidance for the decontamination, sampling, and verification sampling of energetic contaminated structures is provided in Appendix J.12 (U.S. Navy, undated).

Decontamination samples should be analyzed for potential waste constituents of concern (at a minimum energetics) according to the most recent edition of EPA's *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846*. The protocol for the collection of decontamination samples should be negotiated with the lead regulatory agency. Frequently the lead agency will have its own policy regarding decontamination sampling and decontamination effectiveness criteria.

USACHPPM is a technical resource regarding wipe sample screening criteria and should be consulted if wipe samples will be used (http://chppm-www.apgea.army.mil/). But not all surfaces are conductive for wipe sampling. Wipe samples should be limited to nonporous surfaces when destruction sampling is not an option. Areas where wipe samples are to be collected should be cleaned before sampling. However, an alternative (and generally preferred) approach to wipe sampling is rinsate sampling.

Sect. 9.2.2.4 provides applicable guidance for the disposition of existing structures.

9.3.4 Soil Removal and Remediation

9.3.4.1 Soil Removal

If soil concentrations at the unit exceed risk-based levels, the closure plan should describe how soil remediation should be conducted. Typically, the remedy is incremental soil removal until the remaining concentration levels are below risk levels. Soil removal should center around areas of known or suspected contamination. These are areas immediately surrounding the burn pans or trenches, OD craters, and areas where herbicides may have been used to control vegetation.

Soil removal usually involves removing soils that do not meet cleanup standards using backhoes or other excavation equipment. The closure plan should stipulate that the soil should be removed in layers up to a specified thickness from an area extending a specified distance beyond the original location of each of the burn pans, OB trenches, OD craters, or areas of devegetation. Verification sampling should be conducted by taking samples from the sides and bottom of the excavation to determine if cleanup goals have been obtained. If they have, no additional excavation should be necessary. If not, the excavation should proceed laterally and vertically in specified increments, depending on the areas where cleanup standards were not achieved. This process of excavation/verification sampling should be repeated until cleanup goals have been obtained.

If soil removal is necessary, a bermed staging area should be installed at the unit. Soil should be placed in plastic-lined, tarped, roll-off boxes in the bermed staging area. Excavated soil should be sampled to determine whether it should be disposed of as a hazardous or solid waste. The most recent edition of Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, Volume II: Field Manual (USEPA, December 1996) should be used in determining sampling methodology, including the number of samples to be collected and sample locations. The excavated soil should be sampled only for the selected constituents that exceed the risk-based levels (i.e., the constituents for which cleanup is being conducted). Laboratory analyses should be performed using specified test methods. Additionally, field blanks, rinsate blanks, trip blanks, and duplicates should be collected in accordance with specified procedures.

As described in Sect. 9.2, if the excavated soil exhibits a characteristic of a hazardous waste, it should be managed in accordance with RCRA Subtitle C regulations; removed soils that do not exhibit a characteristic of a hazardous waste may be sent to a RCRA Subtitle D solid waste disposal facility in accordance with state and local regulations.

9.3.4.2 Soil Remediation

Soil remediation (as an alternative to soil removal) at OB/OD units will frequently involve the treatment of inorganics and/or energetic constituents. Thermal treatment may be a viable approach for the treatment of energetics. Site-specific factors should be evaluated to determine whether thermal treatment is cost effective. Alternative technologies continue to evolve for the treatment of inorganics and energetics in soil. Examples of these alternatives include bioremediation, plant uptake, and soil-washing technologies. Again, the applicability of these approaches should be evaluated on a case-by-case basis.

USAEC has established an information resource for remediation technologies on its web page (http://aec-www.apgea.army.mil). Information includes a comprehensive Remediation Technologies Screening Matrix and Reference Guide as well as individual scenarios of remediation technologies. A select set of information from the USAEC web page relevant to OB/OD unit closures is presented in Appendix J.11. However, the web page should be directly consulted to obtain updated additional information.

9.3.5 Groundwater Remediation

If it is determined that the groundwater is contaminated, the closure plan should state that it will be treated using an appropriate technology based on the hazardous constituents present and their concentration levels. Technologies that may be considered include pumping and treating of groundwater (e.g., use of ultraviolet oxidation or granulated activated carbon) with the reinjection of treated groundwater, or hydraulic containment (e.g., construction of a slurry wall). Alternative technologies continue to evolve (e.g., phytoremediation treatment of energetic constituents in groundwater). A select set of information on groundwater treatment technologies is presented in Appendix J.11. The USAEC web page (http://aec-www.apgea.army.mil) should be consulted for updated additional information.

9.3.6 Clean Closure Verification Sampling

The closure plan should describe how clean closure of the site is verified, focusing on the verification sampling strategy. Therefore, these procedures should be described in a separate section of the closure plan. The specific sampling procedures (e.g., lab spikes, chain-of-custody) are discussed in detail in Sect. 6 of this guidance.

9.3.6.1 Soil Sampling

The closure plan should state that, following soil excavation, verification sampling will be conducted to confirm that all soils that do not meet the cleanup standard have been removed. The verification sampling should consist of collecting grab samples from the bottom and sides of the excavation at a specified rate of samples per square foot of disturbed surface area. All samples should be taken from depths of 1 to 6 in below the excavated surface grade. All sampling, including QA/QC sampling, should be collected in accordance with a site-specific SOP.

The surface soil samples should be collected after initial excavation activities are completed in that area. The samples are to be submitted to the laboratory and analyzed on a 24-hr turnaround basis to expedite the backfilling process. If the samples are determined to contain OB/OD constituent concentrations above cleanup standards, additional excavation should be performed to remove these soils. The extent of the additional soil removal should be determined in the field. After the second round of excavation, additional soil samples should be collected from the bottom and sides of the new excavation and the process repeated until cleanup standards are achieved.

9.3.6.2 Groundwater Sampling

Groundwater sampling techniques should be the same as those employed in the groundwater monitoring program (see Sect. 6, Investigative Techniques).

9.3.7 Equipment Decontamination

The closure plan should describe how all sampling equipment, hand tools, and heavy equipment will be decontaminated. The suggested approach is that these items be decontaminated at a staging area located at or near the closing unit. The closure plan should note that a staging area will be constructed only if remediation is necessary; otherwise, small equipment and hand tools should be decontaminated at a location convenient to the sampling locations, and containerized wastes could be either accumulated at the unit or sent to a nearby generator storage or permitted/interim status storage unit.

As described in Sect. 9.3.2.2, if a staging area is to be used, it should consist of a compacted earthen foundation surrounded by 1-ft-high earthen berms. The foundation and berms should be overlain by a 30-mil-thick HDPE liner of sufficient durability to withstand decontamination activities. Sand or similar material should be spread on top of the liner to prevent tearing. Ramps should be positioned at the entrance and exit of the decontamination pad to allow vehicles to pass over the berms.

Specific design features to facilitate equipment decontamination include sloping and catch basins. The staging area should be graded to slope toward a corner so that decontamination fluids from steam-cleaning of large construction and drilling equipment will collect in a lined catch basin. The catch basin should consist of a plastic-lined 55-gal drum recessed into the earth. The liner should overlap the drum in such a way that decontamination fluids from the area will feed into the drum through gravity and not to the surrounding soil underneath the liner. Decontamination solutions should be removed from the drum via pump and transferred to leakproof DOT-approved shipping containers and placed in the staging area. Temporary/portable secondary containment devices should be used for all liquid containers.

Run-on should be precluded through use of the berm/liner system, as should run-off. The staging area should be covered with plastic sheeting at the end of each day, when no decontamination activities are in progress, and during precipitation events to prevent accumulation of rainwater in the bermed staging area.

Heavy equipment used for remediation (if necessary) should be decontaminated by brushing, scraping, or shaking, because all contaminated wastes/media are expected to be solids. Residues should be collected with a broom and shovel, containerized, and placed in the staging area. If mechanical removal is not effective, as determined by visual observation, high-pressure steam should be used to decontaminate areas of the heavy equipment. Liquids used in heavy equipment decontamination (if mechanical methods are not appropriate or successful) should be collected in leakproof DOT-approved shipping containers and stored in the staging area. Temporary/portable secondary containment devices should be used for all liquid containers.

All drilling equipment used for the collection of soil samples should be steam-cleaned or washed with high-pressure water prior to the beginning of work, between soil boring locations to prevent cross-contamination of samples, and before leaving the OB unit.

All sampling equipment should be decontaminated before sampling and between samples. The following decontamination steps should be conducted in the order listed:

- Potable water rinse,
- Alconox or liquinox detergent wash,
- Potable water rinse,
- Distilled/deionized water rinse,
- 10% nitric acid rinse diluted with distilled and deionized water,
- Distilled/deionized water rinse,
- Isopropanol double rinse,
- Distilled/deionized water rinse,
- Air dry, and
- Wrap in aluminum foil.

Decontamination solutions from sampling equipment should be collected separately from the steam-cleaning decontamination fluids or from fluids generated during decontamination of any satellite accumulation areas.

Decontamination water used for cleaning drilling equipment, decontamination solutions used for cleaning sampling equipment, and drill cuttings generated during collection of subsurface soil samples are considered IDW and should be managed accordingly (see Sect. 9.2.2.5 of this guidance).

9.3.8 Equipment Decontamination Verification Sampling

The closure plan should describe the sampling procedures for verifying the effectiveness of decontamination of the equipment. (Verification sampling for existing structures was discussed in Sect. 9.3.3 and is also relevant for equipment decontamination verification sampling.)

9.3.9 Followup and Other Activities

After remediation of burn trenches and OD units, the area should be backfilled with clean soil and seeded with native grasses. These procedures should be described in the closure plan.

After the final wastes have been removed from the staging area, the closure plan should describe how the liner and sand will be removed, the berms leveled, the drums removed, and the catch basin filled with clean soil from onsite. The liner and sand should be sampled and analyzed using the same methods and analytes described above to determine if they are hazardous wastes.

The closure plan should also describe how a bound, weatherproof site logbook will be maintained throughout the closure process. This book should contain a summary of the day's activities and should reference the field notebooks when applicable. All information related to sampling or field activities should be recorded in the field notebook. This information should include, but not be limited to, sampling time, weather conditions, unusual events, field measurements, and descriptions of photographs.

9.4 SCHEDULE FOR CLOSURE AND CERTIFICATION

This section of the closure plan should address the following requirements (see Fig. 9-6):

- Timetable for closure activities,
- Total time required to close the unit,
- Estimated year of final closure,
- Extension of closure time, and
- Closure certification.

9.4.1 Timetable for Closure Activities

The closure plan should state that closure should begin immediately after approval of the plan. The closure plan should also include a timetable showing a schedule of closure activities.

9.4.2 Total Time Required to Close the Unit

The closure schedule presented in the closure plan should be consistent with applicable closure regulations. These requirements are discussed in detail in Sect. 4 of this guidance.

9.4.3 Estimated Year of Final Closure

For closure plans submitted with Part B permit applications, an estimate of the year of closure is required for those facilities that use trust funds to establish financial assurance. These regulations exist in order to assess the adequacy of financial assurance provisions, which in the case of Federal facilities are not applicable. However, for closure plans for facilities closing under interim status, this requirement also applies to facilities without an approved closure plan. Therefore, closure plans submitted for OB/OD units closing under interim status must provide this estimate.

9.4.4 Extension of Closure Time

Closure regulations provide owners/operators a means by which to request an extension of the closure period. If closure is expected to be initiated and completed within the allowed period, an extension should not be requested. However, if it is anticipated that a longer closure period is required (e.g., in cases where a year's worth of groundwater data is required to perform a statistical analysis), both a request for an extension and justification for the request should be included in the closure plan (see Sect. 4).

9.4.5 Closure Certification

The closure plan should state that within 60 days following completion of closure of the unit, the owner/operator will submit to the appropriate Regional Administrator, by registered mail, a certification that the unit has been closed in accordance with the approved closure plan. The certification should be signed by the installation commander or his/her delegatee and by an independent professional engineer who is registered in the state where the installation is located. Documentation supporting the engineer's certification should be furnished to the EPA Region upon request.

If the installation has closed under BRAC and there is no longer an installation commander, the commander (or other point of contact) of the installation that has assumed control over the transfer of the facility should sign any required certifications.

9.5 CONTINGENT CLOSURE PLAN

If the goal of the closure plan is clean closure, the plan should include a contingent closure plan that will be implemented in case the clean closure performance standard cannot be achieved (see Fig. 9-7) pursuant to the EPA permit writers' guidance for OB/OD units (USEPA, June 1997). The closure plan should stress that the contingent closure plan should be implemented only after it has been determined that achieving closure standards is not feasible. As such, the contingent closure plan describes how OB/OD units will be closed with waste in place (i.e., as landfills) requiring post-closure care.

Under a contingent closure plan, the OB/OD unit should be closed in a manner that minimizes or eliminates threats to human health and the environment and minimizes the potential for escape of any possible hazardous waste, hazardous constituents, leachate, or waste decomposition products to groundwater, surface water, or the atmosphere. A contingent closure plan should describe the following three contingent closure scenarios:

- Soil with OB/OD constituents above cleanup standards cannot be effectively removed, and groundwater constituents also exceed cleanup standards.
- Soil with OB/OD constituents above cleanup standards cannot be removed, but the groundwater does not require remediation.
- Soil with OB/OD constituents above cleanup standards can be removed, but the groundwater has constituents above cleanup standards levels.

If soils within the unit cannot be fully decontaminated to concentrations at or below risk-based levels, the contingent closure plan should state that the unit will be closed with waste in place. Further, if the groundwater remains above risk-based levels, groundwater cleanup actions should be evaluated and implemented as appropriate. Groundwater monitoring should continue until OB/OD constituents are shown to be below cleanup standards. Run-on and run-off controls should consist of a silt fence to prevent run-on to the area and to keep run-off that leaves the unit from adversely affecting adjacent areas. The content of this type of contingent closure plan is discussed below.

The contingent closure plan should state that everything up to, but not including, soil and groundwater remediation described in the closure plan will still be performed (i.e., removal of wastes and decontamination of existing structures). As such, the contingent closure plan need only reference these steps described above. However, there may be cases when the owner/operator may be in the process of remediation under the clean closure plan and realize that clean closure is not feasible. The contingent closure should address this possibility by including a statement that some remediation may already have occurred at the time the contingent closure plan is implemented.

In addition to normal closure steps, a final cover should be installed over the unit. Landfill closure standards in 40 CFR 264.310(a)(5) state that the cover must have a permeability of less than or equal to the permeability of any bottom liner system or natural subsoils present. A clay cap or even compacted soil may be acceptable. Therefore, the contingent closure plan should state that the contaminated soil will be overlain by a vegetated layer of clay or compacted soil. Note that if partial closure is being conducted, the cover may remain unvegetated.

In certain cases, however, especially in highly sensitive environments, a single clay or soil layer may not be acceptable to the regulators. In this case, a more stringent cap may need to be negotiated. For example, a cover may need to consist of a multilayer clay cap with a synthetic liner. In this case, the cover should be constructed with a permeability of less than or equal to 1×10^{-7} cm/s and should be gently sloped (approximately 4°). The cap should be installed following grading of the area. The synthetic liner should be constructed of 30-mil HDPE and should be placed over the unit after grading. The remainder of the cover should consist of 8 in. of natural clay overlain by a 12 in. soil layer and should be reseeded with sufficient native grasses. The area should then be contoured in an effort to promote drainage and minimize erosion. The entire cover, including the final topsoil cover material, should be of sufficient thickness and elasticity to accommodate settling and subsidence.

Run-on and run-off control systems should also be installed to divert run-on from entering the unit area and to prevent run-off from adversely affecting adjacent areas. This system should consist of a dike that should be a natural extension of the clay cover system described above. The dike should be designed to prevent run-on from entering the unit area during peak discharge from at least a 24-hour storm. The run-off management system should be designed to collect and control at a minimum the water volume resulting from a 24-hour, 25-year storm.

Access to the unit should be controlled by installing a fence with locked gates. Warning signs should be placed at the gate and at 50-ft intervals around the unit.

Groundwater monitoring should be conducted to monitor the groundwater downgradient of the unit during the 30-year post-closure period. This system should be described in detail in the post-closure plan. If the system is similar to the system that would be used during closure, the contingent closure plan may reference those sections of the closure plan where the system is described.

Groundwater quality should be evaluated to determine remedial options that may be appropriate. These may include, for example, pump-and-treat technologies, grout curtains, biodegradation, and others. If soils have been removed from the unit, the cover should consist of 1 ft of clean soil, which should be reseeded using native grasses as described above. No run-on or run-off controls should be established.

As in the clean closure scenario, a closure schedule must be included if the unit is closed in accordance with the contingent closure plan.

9.6 POST-CLOSURE PLAN

If the goal of the closure plan is clean closure, as discussed above, there is always the possibility that the clean closure performance standards are not attainable. In such cases, the OB/OD unit will have to be closed as a landfill under the contingent closure plan and undergo 30 years of post-closure care. Therefore, all closure plans must have a post-closure plan as a discrete component. The post-closure plan itself should contain components that address the following (see Fig. 9-8):

- Inspection plan,
- Monitoring plan,
- Maintenance plan,
- Security, and
- Contact.

A post-closure permit application (or alternative enforceable document) will be needed when closure with waste in place is imminent. The contents for a post-closure care permit application has been specified in 40 CFR 270.28 pursuant to the October 1998 RCRA closure/post-closure amendments. A summary of these information requirements is presented in Fig. 9-9.

9.6.1 Inspection Plan

The post-closure plan should describe how inspections will be conducted during the post-closure care period to mitigate the potential for migration of constituents from OB/OD operations into soil, groundwater, surface water, and air, and to protect public health, safety, and the environment. Inspections should be conducted whenever groundwater sampling events occur—at a minimum, semiannually. Inspections should also occur following all 25-year storm events. Items to be inspected are as follows:

- Security. The OB/OD area should have a locked gate on the access road leading onto the grounds. The gate and accompanying warning sign should be checked for damage.

- Erosion. The cover should be inspected for signs of erosion and for erosion damage, such as might result from washouts.

- Cover settlement. The cover should be inspected for ponding and other indications of excessive settlement, subsidence, or displacement.

- Vegetative cover. The condition of the vegetative cover should be inspected for adequacy and bare spots.

- Run-on and run-off controls. Drainage channels and berms designed to divert and collect stormwater should be checked to ensure positive drainage. The overall integrity of the dike system should be checked.

- Monitoring wells. The condition of the well casing, cap, and lock should be checked at the time the well is sampled.

The various inspection findings and actions should be documented in the facility post-closure inspection logbook.

9.6.2 Monitoring Plan

The post-closure plan should describe the groundwater monitoring that will be conducted during specified intervals throughout the 30-year post-closure period. If the same groundwater monitoring program described above for demonstrating clean closure will be implemented during post-closure care, the post-closure plan may reference appropriate sections of the closure plan.

9.6.3 Maintenance Plan

The post-closure plan should describe the preventive and corrective procedures implemented during post-closure maintenance. These procedures include:

- Security. Signs should be replaced if they become illegible. The gate should be repaired or replaced as necessary to maintain unit security.

- Erosion. Washouts should be repaired whenever they are detected. If the cap integrity is in question, repair activities should be initiated immediately. Restoration of the vegetative cover should be performed as needed.

- Cover settlement. Settlement should be repaired by replacing cover materials and reseeding.

- Vegetative cover. Maintenance of the vegetative cover should include seeding as needed. Tree or bush growth should be controlled by mowing. Mowing should be performed as necessary to control the growth of the vegetative cover and to maintain it at a reasonable height above the cover.

- Run-on and run-off controls. Drains and ditches should be cleaned and maintained to allow free drainage so that stormwater is not retained. High-rate run-off areas (if any) should be protected with coarse stone to ensure that erosion is minimal.

- Monitoring wells. Any damage to monitoring wells should be repaired. If necessary, damaged monitoring wells should be replaced.

9.6.4 Post-Closure Security

There may no longer be personnel at the facility during post-closure. Therefore, the security measures taken during post-closure care may differ from those implemented during closure. Access to the unit during post-closure would most likely be controlled through a locked gate and a warning sign placed at the gate.

Any post-closure security measures should be described in the plan. If these measures are identical to the closure security measures described above, the post-closure plan may reference appropriate sections of the closure plan.

9.6.5 Post-Closure Contact

All post-closure plans should provide the name, address, and telephone number of a person who may be contacted during post-closure care. For some DOD installations closing under BRAC, there may be no one left at the installation. Therefore, the contact does not necessarily have to reside at or near the installation. The person should, however, be familiar enough with the installation to answer questions regarding the manner in which the facility was closed and the status of post-closure care (e.g., the BRAC coordinator).

9.7 NOTICES FOR LAND DISPOSAL FACILITIES

In case the OB/OD unit must close as a landfill under the contingent closure plan, certain notices must be provided. The closure plan must describe how the following notification requirements will be fulfilled (see Fig. 9-10):

- Certification of closure,
- Survey plat,
- Notice to local land use authority,
- Post-closure certification, and
- Notice in deed to property.

9.7.1 Certification of Closure

Within 60 days after the completion of closure of the unit as a disposal unit, DOD should provide the appropriate EPA region and state, by registered mail, a certification by an independent professional engineer who is registered in the state where the installation is located that the unit has been closed in accordance with the contingent closure plan. The certification should be signed by both the registered professional engineer and the Installation Commander or his/her delegatee.

The independent registered professional engineer should certify that each phase of closure was conducted in accordance with the specifications in the contingent closure plan. The following actions should be certified as being in accordance with the contingent closure plan:

- Installation of the multilayer cover is in accordance with engineering drawings and specifications.

- Cover meets established permeability requirements.

- Seeding and grading of vegetative layer meet contours of surrounding area.

Upon completion of contingent closure activities, a final inspection should be conducted to confirm that all requirements of the contingent closure plan have been satisfied.

The installation commander or his/her delegatee should certify that, to the best of his or her knowledge, all specifications in the contingent closure plan were performed as required, and that all required notifications were made to the appropriate agencies.

If the installation has closed under BRAC and there is no longer an Installation Commander, the commander (or other point of contact) of the installation that has assumed control over the transfer of the facility should sign any required certifications.

9.7.2 Survey Plat

If the contingent closure and post-closure plans are implemented (thus, the unit is closed as a landfill), a survey plat must be prepared indicating the locations and dimensions of the wastes in the unit with respect to permanently surveyed benchmarks. The closure plan should state how this will be performed.

The survey plat should be prepared and certified by a professional land surveyor who is registered in the state where the installation is located. The plat should contain a note, prominently displayed, which states DOD's and any future property owner's obligation to restrict disturbance of the wastes contained in the disposal unit. DOD should submit this plat to the appropriate county Planning and Zoning Commission and state environmental agency. This survey plat should be submitted to the required agencies prior to the submittal of the certification of contingent closure activities.

9.7.3 Notice to Local Land Use Authority

The closure plan should state that within 60 days after the certification of contingent closure activities, DOD will submit to the appropriate county Planning and Zoning Commission and state environmental agency a record of the type, location, and quantity of the wastes disposed of within the unit.

9.7.4 Post-Closure Certification

The closure plan should state that within 60 days after the completion of the established post-closure care period for the unit, DOD will provide the appropriate EPA Region, by registered mail, a certification by an independent professional engineer who is registered in the state where the installation is located that post-closure care was performed in accordance with the specifications of the approved contingent post-closure plan. The certification should be signed by both the registered professional engineer and the Installation Commander or his/her delegatee.

If the installation has closed under BRAC and there is no longer an Installation Commander, the commander (or other point of contact) of the installation that has assumed control over the transfer of the facility should sign any required certifications.

9.7.5 Notice in Deed to Property

The closure plan should state that within 60 days after the certification of contingent closure activities, DOD will record, in accordance with state laws, a notation on the deed to the facility property. This notation should, in perpetuity, notify any potential purchaser of the property of the following:

- The land has been used for the open burning and/or open detonation of materials, and hazardous wastes remain in place.

- Its use is restricted, in that the integrity of the final cover, liners, any containment systems, and monitoring systems must never be allowed to be disturbed.

- The survey plat and record of the type, location, and quantity of hazardous wastes disposed of have been filed with the appropriate county Planning and Zoning Commission and state environmental agency.

A certification stating that the above notation has been recorded should be provided to the appropriate state and EPA Region. The certification should be signed by the Installation Commander or his/her delegatee. Additionally, a copy of the document in which this notation has been placed should be sent to the state and EPA Region.

If the installation has closed under BRAC and there is no longer an Installation Commander, the commander (or other point of contact) of the installation that has assumed control over the transfer of the facility should sign any required certifications.

A notification should also be placed in the property's historic file, which is located in the Directorate of Public Works Real Property Section. A copy of the historic file is provided to the new owner or to the lessee in the event of a transfer of property.

9.8 ADDITIONAL INFORMATION

The closure plan should also address requirements for cost estimate and financial assurance mechanisms (see Fig. 9-11).

9.8.1 Cost Estimate

This section of the plan need only provide a statement that no closure or post-closure cost estimate is required for Federal facilities.

9.8.2 Financial Assurance Mechanisms

This section of the closure plan need only provide a statement that financial assurance requirements are not applicable to Federal facilities.

APPENDICES

- APPENDIX A - SUBPART X CLOSURE PLAN REGULATORY COMPLETENESS CHECKLIST
- APPENDIX B - REFERENCES
- APPENDIX C - GLOSSARY OF TERMS
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- APPENDIX H - UXO SAFETY/MANAGEMENT PROCEDURES
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APPENDIX A
SUBPART X CLOSURE PLAN REGULATORY COMPLETENESS CHECKLIST
(USEPA, MARCH 1992)

Checklist for Technical Review of RCRA Part B Permit Application for Subpart X Units

II. PART B GENERAL INFORMATION REQUIREMENTS

Item	Authority	Comments on Requirements	Location of Information in the Application	Addressed (Y/N)	Technically Adequate (Y/N)	See Attached Comment Number
Monitor for leaks, pressure buildup, gas generation or ruptures of released material	40CFR264.56(f)	This item applies if facility stops operations.				
Procedures for preventing handling of incompatible wastes until cleanup is complete	40CFR264.56(h)(1)					
Decontamination procedures	40CFR264.56(h)(2)	Decontamination is required for emergency equipment.				
Notification of EPA and state and local authorities before resuming operations	40CFR264.56(i)	EPA (or state) must be notified within 15 days of occurrence.				
Procedures for record keeping and reporting to EPA	40CFR264.56(j)					
E. PERSONNEL TRAINING						
Outline of both the introductory and continuing training programs	40CFR270.14(b)(12)	All facility personnel must be trained to perform their duties safely.				
A description of how training will be designed to meet actual job tasks	40CFR270.16(a),(b), and (c)	The training must be conducted by a qualified person; there must also be an annual review of the training.				
Training for emergency response	40CFR264.16(a)(3)	Personnel must be made familiar with emergency procedures, emergency equipment, and emergency systems.				
Maintenance of training records/copy of personnel training documents	40CFR264.16(d)(e) and 270.14(b)(12)	The owner or operator must maintain records of job titles, names of employees, job descriptions, and the types and amount of training given to each employee.				
· Training content, frequency, and techniques		Training must also be applicable to site conditions.				
· Training director is properly trained						
F. CLOSURE AND POST-CLOSURE PLAN						
F1. Closure Plan Documentation	40CFR270.14(b)(13)					
Description of partial or final closure procedures	40CFR264.112(b)(1) and (2)	Final closure must minimize the need for further maintenance and must control post-closure release to ground water, surface water, soil, and the atmosphere.				
Description of maximum unclosed portion during the active life of the facility	40CFR264.112(b)(2)					
Estimate of maximum waste inventory in storage and treatment during facility life	40CFR264.112(b)(3)					
Description of procedures for removal or decontamination of hazardous waste residues, equipment, structures, and soils	40CFR264.112(b)(4) and 264.114					
· Location of disposal facility (equipment, structures, and soils when removed)						
· Methods for sampling and testing surrounding soils						
· Criteria for determining decontamination levels						
Description of additional activities performed during closure:	40CFR264.112(b)(5)					
· Ground water monitoring						
· Leachate collection						
· Run-on and run-off control						

Checklist for Technical Review of RCRA Part B Permit Application for Subpart X Units II. PART B GENERAL INFORMATION REQUIREMENTS							
	Item	**Authority**	**Comments on Requirements**	**Location of Information in the Application**	**Addressed (Y/N)**	**Technically Adequate (Y/N)**	**See Attached Comment Number**
	Description of closure schedule including:	40CFR264.112(b)(6) and 264.113					
	· Total time to close each unit		The hazardous waste must be treated, removed, or disposed of within 90 days after receiving the final volume of waste; all closure activities must be completed within 180 days after receiving the final volume of waste.				
	· Timetable of closure activities						
	Estimate of year of closure	40CFR264.112(b)(7)	Estimate of year of closure is required for those facilities that use trust funds to establish financial assurance and are expected to close before expiration of the permit.				
	Extension of closure time	40CFR264.113(a) and (b)	Justification is required if extension is expected to exceed 90 days for treatment, removal, and disposal of wastes and 180 days for completion of closure activities.				
F2.	**Copy of Post-Closure Plan**	40CFR264.117, 264.118, and 264.603	Post-closure plan is expected when the OB/OD unit incorporates the soil as part of the zone of engineering control, unless clean closure is to be attained.				
	Post-closure care mechanisms	40CFR264.603	This includes procedures to prevent any releases that have adversely affected human health or the environment due to migration of wastes in the ground water, surface water, wetlands, soils or air.				
	Description of maintenance, monitoring, inspection, and frequencies for:	40CFR264.118(b)(1) and (2)					
	· Waste-fabricated structures						
	· Facility monitoring equipment						
	Identification and location of person responsible for storage and for updating facility copy of post-closure plan during post-closure period	40CFR264.118(b)(3)					
	Procedure for updating all other copies of post-closure plan	40CFR264.118(b)(2)	A procedure is required to cover changes in operating plans, facility design, expected years to closure, or other events.				
F3.	**Copy of Most Recent Closure and Post-Closure (if applicable) Cost Estimates**	40CFR264.142, 264.144, and 270.14(b) (15) and (16)	Cost estimates must be detailed and assume the hiring of a third party to conduct closure and post-closure care.				
F4.	**Copy of Documents Used as Financial Assurance Mechanisms**	40CFR264.143, 264.145, and 264.146	For new facilities, the documentation may be substituted up to 60 days before initial receipt of hazardous waste.				
	Financial assurance document for closure						
	Adequacy of document						
	Copy of document						
F5.	**Documentation of Notice of Deed**	40CFR270.14(b)(14) and 264.119	This notice applies to a closed unit.				

Checklist for Technical Review of RCRA Part B Permit Application for Subpart X Units II. PART B GENERAL INFORMATION REQUIREMENTS						
Item	Authority	Comments on Requirements	Location of Information in the Application	Addressed (Y/N)	Technically Adequate (Y/N)	See Attached Comment Number
F6. Copy of Insurance Policy	40CFR264.147					
Coverage for sudden accidental occurrences	40CFR264.147(a)	Liability coverage of $1 million per occurrence and $2 million for annual aggregate is required.				
Coverage for nonsudden accidental occurrences	40CFR264.147(b)	Liability coverage of $3 million per occurrence and $6 million for annual aggregate is required.				
G. PROTECTION OF GROUND WATER						
Unit is a regulated unit	40CFR270.14(c), 270.23(b), and 264.90(a)(2)	Protection of ground water must be addressed only for regulated units.				
Existing ground water monitoring data	40CFR270.14(c)(1) and 270.23					
Identification of upper-most aquifer and aquifers hydraulically interconnected beneath the facility property	40CFR270.14(c)(2) and 270.23					
Ground water flow, direction, rate, and source of information	40CFR270.14(c)(2) and 270.23					
Description of any plume of contamination that has entered the ground water from a regulated unit	40CFR270.14(c)(4) and 270.23					
· Indication of the extent of the plumes on the topographic map	40CFR270.14(c)(4)(i), 264.600, and 270.23					
· Concentration of pollutants in the plume	40CFR270.14(c)(4)(ii)	The description must identify constituents of 40CFR264 Appendix IX, waste open burned or detonated, and potential compounds formed in OB/OD.				
Proposed ground water monitoring program	40CFR270.14(c)(5), 264.97, 264.600, and 270.23					
· Description of well design and location	40CFR264.97, 264.600, and 270.23	The description should include discussion or inspection of well to withstand OB/OD or other activities.				
· Sample collection	40CFR264.97(d)(1), 264.600, and 270.23					
· Sample preservation and shipment	40CFR264.97(d)(2), 264.600, and 270.23					
· Sampling and analysis procedures	40CFR264.97(d)(3), 264.600, and 270.23					

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APPENDIX B
REFERENCES

APPENDIX B. REFERENCES

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APPENDIX C
GLOSSARY OF TERMS

APPENDIX C. GLOSSARY OF TERMS

Active Life: The period from the initial receipt of hazardous waste at the unit until the regulator receives certification of final closure.

Administrative Closure: The term that is used to refer to a closure process that does not involve remediation either because remediation is not necessary or because it is being deferred (e.g., until range cleanup occurs) for OB/OD units located within active range.

Approved Closure Plan: A closure plan that has been approved by a regulator during interim status or in the course of RCRA permitting.

BangBox: A test chamber used to measure OB/OD emissions.

Characteristic Waste: A solid waste that is hazardous because it exhibits one of the following four characteristics of hazardous waste—ignitability, corrosivity, reactivity, or toxicity.

Clean Closure: Closure that is accomplished by removing all wastes from a hazardous waste management unit and/or decontaminating the hazardous waste management unit.

Closure: The process of terminating operations at RCRA-regulated hazardous waste management units, including OB and OD units.

Closure Plan: A plan describing how closure will be accomplished in accordance with general closure performance standards and unit-specific closure standards.

Composite Sample: Sample which consists of equal sampling quantities from multiple locations and uniformly mixed.

Conceptual Closure Plan: A closure plan that presents a closure concept to a regulator. Once agreement between the facility and the regulator is reached on a closure concept, the facility can develop an actual closure plan.

Contingent Closure Plan: A closure plan describing how closure as a landfill will be accomplished in the event that clean closure cannot be achieved. (Regulators have been requiring contingent closure plans for OB and OD units where clean closure is planned.)

Contingent Post-Closure Plan: A post-closure plan required for units where clean closure is planned. The post-closure plan is necessary in the event that clean closure cannot be accomplished and the unit must close as a landfill. (Regulators have been requiring contingent post-closure plans for OB and OD units where clean closure is planned.)

Corrective Action: The process of remediating releases of hazardous waste and hazardous constituents from solid waste management units.

Corrective Measures Implementation: This activity designs, constructs, and operates the corrective measure or measures selected in the Corrective Measures Study.

Corrective Measures Study: This study develops and evaluates corrective measures alternatives which may be applicable to cleanup of documented contaminated sites. It also recommends the most appropriate corrective measure.

Dirty Closure: A closure which does not meet clean closure standards.

Existing Facility: A facility which was in operation or for which construction commenced on or before November 19, 1980.

Exposure Area: Area of exposure for a potential receptor considering land use. An individual is assumed to move randomly over the exposure area over time.

Final Closure: The closure of all hazardous waste management units at a facility.

Impact Area: Area of potential contamination from OB/OD due to ejecta and kickouts for defining soil sampling requirements.

Independent Professional Engineer: A professional engineer who is not a direct employee (i.e., not on the payroll) of the facility owner or operator.

Installation Restoration Program: The Department of Defense program established to identify, investigate, evaluate, and, if necessary, clean up sites to protect human health and the environment.

Interim Measures: Corrective actions to stabilize, control, or limit further releases. Interim measures can be imposed at any point in the Corrective Action process.

Interim Status Facility: A RCRA hazardous waste management facility, regulated under 40 CFR 265, that has not yet received a RCRA permit.

Limited Remediation Closure: Closure which involves some remediation but clean closure standards are not attained.

Listed Waste: A solid waste that is hazardous because it is on one of the three lists of hazardous waste (wastes from non-specific sources, wastes from specific sources, commercial chemical products) developed by EPA.

Miscellaneous Unit: A hazardous waste management unit that does not meet the definition of any other type of specific hazardous waste management unit (i.e., container; tank; surface impoundment; pile; land treatment unit; landfill; incinerator; boiler; industrial furnace; underground injection well; containment building; corrective action management unit; or unit eligible for a research, development, and demonstration permit) regulated under RCRA. Miscellaneous units are regulated under Subpart X of 40 CFR 264. OB and OD units are miscellaneous units.

New Facility: A facility not in existence or under construction on November 19, 1980, or on the effective date of the statutory or regulatory requirements, rendering the facility subject to RCRA permit requirements. A new facility is not eligible for interim status and must receive a RCRA permit before it can begin operation.

Partial Closure: The closure of a hazardous waste management unit at a facility that contains other active hazardous waste management units.

Permitted Facility: A RCRA hazardous waste management facility that has received a permit to operate under 40 CFR 264.

Post-Closure Care: The activities that must be performed at a hazardous waste management unit after closure to ensure that waste containment systems are monitored and maintained. Post-closure care is required at hazardous waste management units that do not clean close.

Post-Closure Plan: A plan that describes how post-closure care monitoring and maintenance activities will be accomplished during the post-closure care period.

Range Rule: A regulation that is being developed by the Department of Defense to address the closure and remediation of military ranges.

RCRA Facility Assessment: Identifies potential or actual contamination releases through a records review and visual examination of every solid waste management unit.

RCRA Facility Investigation: Confirms the existence of contamination and determines its nature. The RCRA Facility Investigation also examines the extent and rate of any migration through the implementation of a work plan. It also provides baseline data for the evaluation of corrective measures.

Record of Decision: A decision document, signed by the Assistant Administrator of the Office of Solid Waste and Emergency Response (part of EPA), that formally identifies the cost-effective cleanup option (or response action) required to remedy the release of hazardous substances.

Remediation: Cleanup or safeguarding of hazardous wastes.

Removal Action: Any action to reduce or remove the impact of conditions at a site. Time-critical actions begin within six months following the decision to act.

Resource Conservation and Recovery Act of 1976 as amended, 42 U.S.C. §§6901 et seq.: A Federal law that established a regulatory system to track hazardous substances from the time of generation to disposal. The law requires safe and secure procedures to be used in treating, transporting, storing, and disposing of hazardous substances. RCRA is designed to prevent new, uncontrolled hazardous waste sites.

Risk-Based Clean Closure: A type of clean closure that requires the removal of all hazardous waste but the cleanup of hazardous constituents is not necessary if human health and the environment are not endangered commensurate with risk-based cleanup criteria.

Solid Waste Management Unit: Any discernible unit at which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous waste. These units include any area at a facility at which solid wastes have been routinely and systematically released.

Source Area: Area of known contamination from OB/OD (i.e., OB burn areas and OD pits/craters) for defining soil sampling requirements.

Subpart X Unit: A hazardous waste management unit regulated under Subpart X of 40 CFR 264. Subpart X units are miscellaneous units. (See the definition of Miscellaneous Unit.)

Transportation Area: Area of shrapnel due to OB/OD treatment for defining soil sampling requirements.

APPENDIX D
LIST OF ACRONYMS

APPENDIX D. LIST OF ACRONYMS

ADEM	Alabama Department of Environmental Management
AEDA	Ammunition, Explosives, and Dangerous Articles
AMCCOM	U.S. Army Armament, Munitions, and Chemical Command
ARAR	Applicable or Relevant and Appropriate Requirement
ASTDR	Agency for Toxic Substances and Disease Registry
AT	Averaging Time
BMP	Best Management Practice
BRAC	Base Realignment and Closure
BTAG	Biological Technical Assessment Group
BTEX	Benzene, Toluene, Ethyl Benzene, and Xylene
BTX	Benzene, Toluene, and Xylene
CAMU	Corrective Action Management Unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Constituent of Concern
CPC	Constituent of Potential Concern
CSF	Cancer Slope Factor
CTT	Closed, Transferred, and Transferring
dBA	Decibels, A-weighted
DIMP	Diisopropyl methylphosphonate
DOD	Department of Defense
DOT	Department of Transportation
DPG	Dugway Proving Ground
DQO	Data Quality Objective
EA	Exposure Area
ECD	Electron Capture Detector
EFD	Exposure Frequency and Duration
EGDN	Ethylene glycol dinitrate
EOD	Explosive Ordnance Disposal
EPA	U.S. Environmental Protection Agency
EP Tox	Extraction Procedure Toxicity
EqP	Equilibrium Partitioning
ERA	Ecological Risk Assessment
ET	Ecotox Threshold
FDSP	Florida Department of Environmental Protection
FEMA	Federal Emergency Management Agency
FFCA	Federal Facilities Compliance Agreement
FSP	Field Sampling Plan
GC/MS	Gas Chromatograph/Mass Spectrometer
GFAA	Graphite Furnace Atomic Absorption
HCE	Hexachloroethane
HDPE	High-Density Polyethylene
HEAST	Health Effects Assessment Summary Tables

HERO	Hazards of Electromagnetic Radiation to Ordnance
HI	Hazard Index
HQ	Hazard Quotient
HRS	Hazard Ranking System
HSWA	Hazardous and Solid Waste Amendments
ICP	Inductively Coupled Plasma
ICR	Incremental Cancer Risk
ICS	Interference Check Sample
IDW	Investigation-Derived Waste
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
LCS	Laboratory Control Sample
LDR	Land Disposal Restriction
LOAEL	Low Observed Adverse Effect Level
MCL	Maximum Contaminant Level
MEPAS	Multimedia Environmental Pollutant Assessment System
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NEW	Net Explosive Weight
NG	Nitroglycerin
NQ	Nitroguanidine
NIOSH	National Institute of Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level
NOD	Notice of Deficiency
NPL	National Priorities List
OB	Open Burning
OD	Open Detonation
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyl
PETN	Pentaerythritol tetranitrate
PGDN	Propylene glycol dinitrate
PPE	Personal Protective Equipment
QA	Quality Assurance
QC	Quality Control
QAPP	Quality Assurance Project Plan
RAGS	Risk Assessment Guidance for Superfund
RAPS	Remedial Action Priority System
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose
RFI	RCRA Facility Investigation
RI/FS	Remedial Investigation/Feasibility Study
RTECS	Registry of Toxic Effects of Chemical Substances
SAP	Sampling and Analysis Plan
SE	Standard Error

SERDP	Strategic Environmental Research and Development Program
SOP	Standard Operating Procedure
SSHP	Site-Specific Safety and Health Plan
SWMU	Solid Waste Management Unit
TC	Toxicity Characteristic
TCLP	Toxicity Characteristic Leaching Procedure
TNG	Trinitroglycerol (nitroglycerin)
TNT	Trinitrotoluene
TOC	Total Organic Content
TRV	Toxicity Reference Value
TSCA	Toxic Substances Control Act
TSDF	Treatment, Storage, or Disposal Facility
UCL	Upper Confidence Limit
UDEQ	Utah Department of Environmental Quality
UF	Uncertainty Factor
URF	Unit Risk Factor
USACE	U.S. Army Corps of Engineers
USAEC	U.S. Army Environmental Center
USAEHA	U.S. Army Environmental Hygiene Agency
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USAFACC	U.S. Air Force Air Combat Command
USGS	U.S. Geological Survey
UTS	Universal Treatment Standard
UXO	Unexploded Ordnance
VOC	Volatile Organic Compound
WDOE	Washington Department of Ecology
WP	White Phosphorus

APPENDIX E
ANNOTATED BIBLIOGRAPHY

APPENDIX E. ANNOTATED BIBLIOGRAPHY

INTRODUCTION

An annotated bibliography has been provided of readily available RCRA closure guideline documents, risk assessment documents, investigation reference documents, etc., to establish a minimum "library" that each office responsible for closure of RCRA OB/OD units should maintain. This bibliography indicates the source where each document can be obtained.

Reference Document	Synopsis	Where to Obtain*
Minor, et al. (Minor, C., E. Goller, A. Stahl, J. Anderson, D., Lawrence, C. Thomas). December 1995. "A Strategy for Achieving Cost Effective Closure of Open Burning/Open Detonation Units," Dames and Moore and US. Air Force.	Discussion of alternative OB/OD closure strategies	Appendix J
U.S. Army, September 1994. Requirements for the Preparation of Sampling and Analysis Plans. EM 200 1-3. U.S. Army Corps of Engineers. Washington, DC.	Guidance for the preparation of sampling and analysis plans.	DTIC
U.S. Army, May 2000. Basic Safety Conception and Considerations for Ordnance and Explosives (OE) Operations. U.S. Army Engineering and Support Center. Huntsville, AL.	Guidance for UXO avoidance.	Appendix H
U.S. Army, April 1996. Generic Scope of Work for Ordnance Avoidance Operations. U.S. Army Engineering Support Center, Huntsville, AL.	Guidance for UXO avoidance.	Appendix H
U.S. Army, April 2000. Engineering and Design – Ordnance and Explosives Responses, Chapter 12 – "OE Detection and Response". U.S. Army Engineering Support Center, Huntsville, AL.	Guidance for UXO	Appendix H
U.S. Army, January 1999. U.S. Army Open Burn/Open Detonation Unit Management Guide. U.S. Army Environmental Center, Aberdeen Proving Ground, MD.	Alternative approaches for management of remediation waste	NTIS
USEPA (U.S. Environmental Protection Agency), 1987. RCRA Guidance Manual for Subpart G Closure and Post User Care Standards and Support H Cost Estimates Requirements. Office of Solid Waste and Emergency Response, Washington, DC.	Generic guidance on EPA closure requirements.	NTIS
USEPA (U.S. Environmental Protection Agency), September 1988. Control of Open Fugitive Dust Sources. Office of Air Quality Planning and Standards, Research Triangle Park, NC.	Guidance for the preparation of site-specific health and safety plans.	DTIC
USEPA (U.S. Environmental Protection Agency, May 1989. Interim Final RCRA Facility Investigation (RFI) Guidance. Office of Solid Waste and Emergency Planning, Washington, DC.	Guidance for the conduct of site investigations.	NTIS
USEPA (U.S. Environmental Protection Agency), January 1992. Checklist for Technical Reviews of RCRA Part B Permit Application. Region 9. San Francisco, CA.	Summary of EPA closure plan requirements for OB/OD units.	DTIC

Reference Document	Synopsis	Where to Obtain*
USEPA (U.S. Environmental Protection Agency), July 1992. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. Draft Addendum to Interim Final Guidance. Office of Solid Waste. Washington, DC.	Technical guidance for the groundwater monitoring data.	NTIS
USEPA (U.S. Environmental Protection Agency), November 1992. RCRA Groundwater Monitoring Draft Technical Guidance. Office of Solid Waste. Washington, DC.	Primary EPA guidance for the design and conduct of groundwater monitoring program.	NTIS
USEPA (U.S. Environmental Protection Agency). February 2000. EPA Reaches Settlement on "CAMU Rule". Office of Solid Waste and Emergency Response. Washington, DC.	Assistance on CAMUs.	EPA Region 6
USEPA (U.S. Environmental Protection Agency), 1995. Test Methods for Evaluating Solid Waste. SW-846, Third Edition, Office of Solid Waste and Emergency Response, Washington, DC.	Standard reference for EPA analytical methods. Also, includes some guidance on sampling location selection and sampling methods.	NTIS
USEPA (U.S. Environmental Protection Agency), July1996. Soil Screening Guidance: User's Guide. Office of Solid Waste and Emergency Response. Washington, DC.	Guidance on the design of soil sampling programs as well as soil screening criteria.	NTIS
USEPA (U.S. Environmental Protection Agency), 1996. ECO Update. Vol. 3: No. 2. EPA 540/F-95/038.	Provides ecological screening criteria.	NTIS
USEPA (U.S. Environmental Protection Agency), September 1996. "Coordination Between RCRA Corrective Action and Closure and CERCLA Site Activities." Office of Solid Waste and Emergency Response, Washington, DC.	RCRA vs. CERLA parity policy.	NTIS/EPA
USEPA (U.S. Environmental Protection Agency). November 1996b. Field Sampling and Selecting On-Site Analytical Methods for Explosives in Soil." Federal Facilities Forum Issue. Office of Solid Waste and Emergency Response, Washington, DC.	Guidance on field screening for explosives.	NTIS/EPA
USEPA (U.S. Environmental Protection Agency), 1997b. "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action and Underground Storage Tank Sites." Office of Solid Waste and Emergency Response, Washington, DC.	Use of natural attenuation for remediation.	NTIS/EPA
USEPA (U.S. Environmental Protection Agency), June 1997a. Subpart X Permit Writers Guidance Document. Office of Solid Waste and Emergency Response, Washington, DC.	Subpart X regulatory guidance for OB/OD units	EPA
USEPA (U.S. Environmental Protection Agency), March 1998. " EPA Risk-Based Clean Closure." Office of Solid Waste and Emergency Response, Washington, DC.	Clean closure policy.	NTIS/EPA
USEPA (U.S. Environmental Protection Agency). October 1998c. Management of Remediation Waste Under RCRA. EPA 530-F-98-026: Office of Solid Waste and Emergency Response, Washington, DC.	Provides information on closure vs. permitting decision making, conduct of site characterization screening assessments, and closure cost estimates.	DTIC

Reference Document	Synopsis	Where to Obtain*
USEPA (U.S. Environmental Protection Agency). Risk-Based Concentration Table. EPA Region 3, Philadelphia, PA.	Human health screening criteria.	EPA Region III
USEPA (U.S. Environmental Protection Agency). Region IX Preliminary Remediation Goals (PRGs). EPA Region 9, San Francisco, CA.	Human health screening criteria.	EPA Region IX
ASTM (American Society for Testing and Materials). 1995. Standard Guide to Corrective Action at Petroleum Release Sites, E.1739-95. Philadelphia, PA.	Tiered human health risk assessment guidance	ASTM
USEPA (U.S. Environmental Protection Agency). July 1998. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities Region 6. Dallas, TX. (http://www.epa.gov/earth1r6/6pd/rcra_c/protocol/protocol.htm).	Human health risk assessment guidance.	Web
USEPA (U.S. Environmental Protection Agency). Risk Assessment Guidance for Superfund (RAGS). This includes multiple documents (as well as associated tools and technical resources) and updates as identified at the USEPA Superfund Risk Assessment web page (http://www.epa.gov/superfund/programs/risk/toolthh.htm).	Human health risk assessment guidance.	Web
Application of USEPA media specific and integrated multi-media models to evaluate the potential for contamination migrations. (http://www.epa.gov/epahome/Data.html).	Human health risk assessment guidance.	Web
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Reference Document	Synopsis	Where to Obtain*
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USEPA Region 4 (U.S. Environmental Protection Agency, Region 4). December 1998. Ecological Risk Assessment at Military Bases: Process Considerations, Timing of Activities, and Inclusion of Stakeholders. Atlanta, GA.	Ecological risk assessment guidance.	Web
USEPA (U.S. Environmental Protection Agency). August 1999. Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Office of Solid Waste. Peer Review Draft, EPA530-D-99-001A. Region 6. Dallas, TX. (http://www.epa.gov/epaoswer/hazwaste/combust/ecorisk.htm).	Ecological risk assessment guidance.	Web
USEPA Integrated Risk Information System (IRIS), (http://www.epa.gov/iris/)	Human health toxicological information	Net
USEPA Health Effects Assessment Summary Tables (HEAST) and other information form the National Center for Environmental Assessments (http://www.epa.gov/ncea/)	Supplemental human health toxicological information	Net
USEPA Criteria Documents (e.g., Health Advisories and Drinking Water Criteria Documents), http://www.epa.gov/ost/drinking/standards/	Supplemental human health toxicological information	Net
Agency for Toxic Substances and Disease Registry (ASTSDR) Toxicity Profiles (http://www.atsdr.cdc.gov/atsdrhome.html)	Supplemental human health toxicological information	Net
Registry of Toxic Effects of Chemical Substances (RTECS) (http://www.cdc.gov/niosh/rtecs.html)	Supplemental human health toxicological information	Net
National Institute of Occupational Safety and Health (NIOSH) (http://www.cdc.gov/niosh/homepage.html)	Supplemental human health toxicological information	Net
Standard Screening-Level Measure of Ecotoxicological Effects	Ecological Risk Assessments	USACHPPM

*NTIS = National Technical Information Service (703) 487-4650
DTIC = Defense Technical Information Center
(703) 274-7882 System Status (Recording)
(703) 274-7251 Technical Control, Telecommunications, Cryptography
(703) 274-7791 Training, Manuals, Search Help
(703) 274-7709 Agnus Taylor, DROLS Service Applications, Passwords Registration

(703) 274-6867 Custom Search/Retrieval Analysis

(703) 274-7791 Record Services (Individual documents only, no subject searches).

APPENDIX F
INFORMATION FROM REGULATORY SURVEY

APPENDIX F. INFORMATION FROM REGULATORY SURVEY

In October 1995, a survey was conducted by Brown & Root Environmental for the purpose of identifying and gathering information from the U.S. Environmental Protection Agency (EPA) and selected states on policy and guidance related to the closure of Subpart X units. The survey consisted of telephone interviews and searches through available electronic databases for Resource Conservation and Recovery Act (RCRA) guidance documents. In addition to EPA Headquarters, EPA Regions (1 through 10) were contacted.

The following list identifies states that participated in the survey or states for which Subpart X and/or closure-related information was collected independently:

- Alabama
- Florida
- Michigan
- Missouri
- Utah
- Washington

This appendix summarizes the EPA and state guidance and policies obtained through this survey.

EPA POLICY AND GUIDANCE

According to EPA Headquarters, at the time of the survey EPA Subpart X policy was still under development. To assist in developing this policy, EPA formed the Subpart X Permit Writers Workgroup, which consists of representatives from EPA Headquarters and each of the EPA Regions. In October 1993, the Permit Writers Workgroup along with the Permits and State Programs Division of the EPA Office of Solid Waste released RCRA 40 CFR Part 264, Subpart X Draft Permit Writers Technical Resource Document. This guidance is being developed to assist EPA Regional and state personnel in evaluating Subpart X permit applications. Currently, the guidance is still in the draft phase. A second draft is being developed.

Risk Assessment

According to EPA Regions, one of the most contentious issues that the Workgroup is undertaking is risk assessment. There is currently no preferred approach for determining the risk posed by open burning/open detonation (OB/OD) operations. Given the wide variety of site-specific conditions, the implementing regulatory agency should remain flexible regarding the approach that should be taken in assessing risk.

Both EPA Headquarters and the Regions stated that for now, with respect to OB/OD unit closure, most regulatory agencies should accept preliminary remedial goals based on EPA's Risk Assessment Guidance for Superfund (RAGS). One Region stated that this approach would include integrating the Comprehensive Environmental Response, Compensation, and Liability Act

(CERCLA) process whenever appropriate, including using available data generated during a Remedial Investigation/Feasibility Study (RI/FS). Based on experience, the Department of Defense (DOD) has found that this approach works successfully. For example, the approach of combining RCRA closure and the CERCLA process was taken in the closure plan for Jefferson Proving Ground. In that case, soil and groundwater sampling conducted during the RI/FS process was used to identify contaminants of potential concern, which are then used in the risk assessment that will be conducted to determine cleanup levels.

Generally, according to the Regions, when a risk assessment is performed for closure of OB/OD units, a residential land use scenario should be considered because, in most cases, the future use of a military reservation is not known at the time of closure.

Universal Clean Closure Standards

According to EPA Headquarters and the Regions, at the time of the survey, the Workgroup had not reached a consensus on how to develop contaminant-specific clean closure standards. For now, permit applicants may use soil screening levels under RAGS, action levels under proposed Subpart S, or guidance for contaminated media to determine if remediation is necessary. However, permit applicants should be careful not to assume that these levels constitute actual cleanup levels; the levels referenced above should be used only as a screening tool to determine if remediation should be performed.

According to one Region, maximum contaminant levels (MCLs) are usually the cleanup standard for groundwater. For constituents without MCLs, the formulas used to derive Subpart S action levels (see Appendix E of proposed Subpart S) may be used to establish cleanup standards (based on a 70 kg person consuming 2 L of water a day). However, states may be more stringent.

The Military Munitions Rule and subsequent Military Range Rule are also expected to influence EPA's policy on clean closure of OB/OD units.[1] These rules should have a particularly profound impact on installations such Jefferson Proving Ground, where a closing OD unit is located on a closed range. These rules will also affect how closure will be performed at installations such as West Point and Fort Drum where OB/OD operations are conducted on active ranges.

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1 USEPA's proposed Military Munitions Rule (60 FR 56468) addresses when munitions become hazardous wastes. The rule also contains a sunset provision that would allow future DOD range cleanup standards to supersede RCRA corrective action at closed, transferred, or transferring ranges.

Sampling and Analytical Techniques

When sampling is performed at OB/OD sites, safety is a concern due to the potential presence of unreacted energetic items and unexploded ordnance (UXO). According to the Regions, sampling and analysis policy with respect to safety is an issue that the Workgroup is currently developing. In the meantime, certain techniques may be employed to reduce the safety risks when performing field work in the presence of UXO. These techniques are discussed in detail in Sect. 6 of this guidance, Investigative Techniques, as well as Appendix H.

Groundwater Monitoring

Because it has been EPA's policy that OB/OD units do not constitute land disposal for the purpose of triggering RCRA's land disposal restrictions, many installations with interim status OB/OD units have not implemented groundwater monitoring programs that comply with 40 CFR Part 265 Subpart F.[2] Since the Subpart X regulations, some regions have clarified the need for groundwater monitoring for OB/OD units. For example, EPA Region 8 states in its Comprehensive Subpart X Policy for Open Burning/Open Detonation Units that permit applicants must install groundwater monitoring wells around each OB/OD unit and monitor for releases of hazardous constituents listed in Appendix IX of 40 CFR 264 (USEPA Region 8, 1991). Similarly, EPA Region 7 states in a letter that OB/OD permit applications must contain a groundwater monitoring program that fulfills the requirements of 40 CFR 264 Subpart F (USEPA Region 7, 1991).

However, installations that have not operated a RCRA groundwater monitoring program prior to closure face a problem when closing an OB/OD unit under interim status. That is, the 180-day closure period is not sufficient to install a groundwater monitoring system and collect enough groundwater data for a statistical analysis. The approach to solving this problem varies between EPA regions. For example, while some regions may prefer a full year of sampling as opposed to one or two rounds that could be performed only during the 180-day closure period, other regions may require that the applicant request an extension of the closure period in order to collect enough data.

Investigation-Derived Waste (IDW)

For guidance on managing IDW during the RCRA closure process, EPA usually refers to its Superfund guidance, Management of Investigation-Derived Wastes During Site Inspections (USEPA, 1991). This guidance basically states that IDW that contains a listed waste or exhibits a characteristic of a hazardous waste must be managed as hazardous. The guidance also allows that certain nonhazardous IDW (soil cuttings, groundwater, and decontamination fluid) may be left onsite without containerization. This guidance basically reiterates EPA's long-standing

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2 The interim status groundwater monitoring requirements in 40 CFR 265 apply only to surface impoundments, landfills, and land treatment units.

contained-in policy, which states that an environmental medium containing a listed hazardous waste must be managed as if it were itself a listed waste until it is effectively decontaminated.[3]

However, the extent of acceptance of this guidance for RCRA closure varies among EPA Regions. For example, some Regions refer to this guidance for RCRA closure, while others prefer that nonhazardous drill cuttings and groundwater be handled under a conservative approach by using drums or roll-off boxes to contain IDW. Under this approach, any IDW that has potentially contacted listed or characteristic hazardous waste should also be managed as hazardous waste.

Some EPA Regions have their own guidance on the management of IDW during RCRA closure. For example, EPA Region 4: Management of Contaminated Media states, "Contaminated media from RCRA closures must be managed as if they were hazardous wastes and must meet Subtitle C requirements as long as they contain a listed waste or exhibit a hazardous waste characteristic. If the medium does not exhibit a hazardous waste characteristic, best management practices apply" (USEPA Region 4, 1992). Note that best management practices (BMPs) may include spreading nonhazardous cuttings over the site. However, EPA regions will defer to states when state requirements are more stringent. As discussed below, Florida has its own guidance on managing IDW.

One Region suggests that IDW be tested using the Toxicity Characteristic Leaching Procedure (TCLP) for toxicity characteristic (TC) constituents. If the test results are positive, the IDW must be managed as hazardous waste.

STATE POLICY AND GUIDANCE

As noted above, states may implement guidance that is more stringent than the policy imposed by their respective EPA Regions. In such cases, EPA Regions will defer to the more stringent policy. Some of these policies are discussed below.

Risk Assessment

The Utah Department of Environmental Quality (UDEQ) has released its draft Permit Writers Guidance for Open Burning and Open Detonation (OB/OD) Treatment Facilities (UDEQ, 1995). Although this document does not address risk with respect to closure, it does require that assessing the risk posed by OB/OD operations be conducted in accordance with EPA's RAGS (UDEQ, 1995).

Also, the Washington Department of Ecology (WDOE) has published extensive guidance on assessing risk and calculating cleanup levels under the Model Toxics Control Act. This methodology may be used in establishing clean closure performance standards for OB/OD units in the State of Washington.

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[3] USEPA's contained-in policy, originally formed in 1985, has been expressed over the years through various letters, memos, directives, and Federal Register preambles.

Universal Clean Closure Standards

According to most Regions, MCLs are usually the cleanup standard for groundwater. However, for constituents without MCLs, some Regions will use a Subpart S action-level formula to establish cleanup standards. However, Florida multiplies the value derived from this formula by a factor of 0.2 to establish cleanup standards. In such case, the Region will defer to the more stringent state levels.

Sampling and Analytical Techniques

UDEQ states in its draft Permit Writers Guidance for Open Burning and Open Detonation (OB/OD) Treatment Facilities that soil sampling must be conducted within a circular area surrounding the OB/OD unit with a radius equal to the minimum safe-setback distance. These distances are also presented in UDEQ's guidance. Sampling should be done in accordance with EPA Method SW-856 guidelines. If the permit applicant proposes an alternative, justification may be required (UDEQ, 1995).

In addition, WDOE's Guidance on Sampling and Data Analysis Methods provides general guidelines on soil and groundwater sampling for the purpose of determining cleanup standards (WDOE, 1995). These guidelines may also be used when closing OB/OD units in the State of Washington.

Groundwater Monitoring

Some installations may not have collected enough groundwater data to perform a statistical analysis at the time of closure. EPA's policy on this issue varies between Regions. State policies also vary from state to state. For example, West Virginia may allow just one round of sampling for closure purposes. However, permit applicants should obtain EPA regional concurrence on this approach, especially in states without Subpart X authority.

UDEQ states in its draft Permit Writers Guidance for Open Burning and Open Detonation (OB/OD) Treatment Facilities that permit applications for OB/OD units must describe groundwater monitoring programs that adequately evaluate the quality of the groundwater beneath the site. Applicants may choose to demonstrate that a groundwater monitoring program is not necessary. To be successful, the demonstration must prove that the OB/OD activities conducted during interim status have not resulted in groundwater contamination (UDEQ, 1995). Although not stated in UDEQ's guidance, it is implied that this demonstration may be used to demonstrate clean closure with respect to groundwater.

Investigation-Derived Waste

The Alabama Department of Environmental Management (ADEM) has issued a Purged Groundwater Management Policy (ADEM, 1992). This policy adopts EPA's contained-in policy but adds that in cases when it is not known if the groundwater contains a hazardous waste, the purged water must be containerized (under RCRA regulations) until the status of the groundwater is determined (ADEM, 1992).

The Florida Department of Environmental Protection (FDEP) in 1995 issued an Interoffice Memorandum on the management of contaminated media under RCRA (FDEP, 1995). This document follows Federal guidance in that IDW exhibiting a hazardous characteristic must be managed as hazardous waste. However, the FDEP establishes more stringent constituent levels that require contaminated soils and groundwater also to be managed as hazardous waste. These levels include EPA's universal treatment standards (UTS) under the land disposal restrictions (LDRs), MCLs, and EPA's soil screening levels under RAGS. Contaminated media with hazardous constituent concentrations below these levels must be managed using FDEP's approved Best Management Practices.

WDOE's Guidance for Clean Closure of Dangerous Waste Facilities basically adopts EPA's contained-in policy for managing contaminated media. The guidance document further states that WDOE will determine that contaminated media no longer contain a hazardous waste when constituent concentrations fall below cleanup levels under residential exposure assumptions (WDOE, 1994).

REFERENCES

ADEM, 1992. Purged Groundwater Management Policy.

EPA, 1991. Management of Investigation-Derived Wastes During Site Inspections.

EPA Region 4, 1992. EPA Region 4: Management of Contaminated Media.

EPA Region 7, 1991. Letter from Harrington (EPA Region 7) to Hart (Sunflower Army Ammunition Plant), May 31.

EPA Region 8, 1991. Comprehensive Subpart X Policy for Open Burning/Open Detonation Units.

FDEP, 1995. Interoffice Memorandum from Kastury to Waste Management Program Administrators, July 27.

UDEQ, 1995. Permit Writers Guidance for Open Burning and Open Detonation (OB/OD) Treatment Facilities (Draft).

WDOE, 1994. Guidance for Clean Closure of Dangerous Waste Facilities.

WDOE, 1995. Guidance on Sampling and Data Analysis Methods.

APPENDIX G
EPA SOIL SCREENING GUIDANCE (JULY 1996)

APPENDIX G
EPA SOIL SCREENING GUIDANCE
(JULY 1996)

http://www.epa.gov/superfund/resources/soil/index.htm

APPENDIX H

UXO SAFETY/MANAGEMENT PROCEDURES

APPENDIX H.1	**U.S. ARMY, HUNTSVILLE - ORDNANCE AND EXPLOSIVES MANDATORY CENTER OF EXPERTISE AND DESIGN CENTER: HOMEPAGE**
APPENDIX H.2	**U.S. ARMY, HUNTSVILLE - ORDNANCE AND EXPLOSIVES MANDATORY CENTER OF EXPERTISE AND DESIGN CENTER: INDEX OF DATA ITEM DESCRIPTION**
APPENDIX H.3	**U.S. ARMY, HUNTSVILLE - ORDNANCE AND EXPLOSIVES MANDATORY CENTER OF EXPERTISE AND DESIGN CENTER: REGULATIONS, GUIDANCE, AND PROCEDURES**

APPENDIX H.1
U.S. ARMY, HUNTSVILLE - ORDNANCE AND EXPLOSIVES MANDATORY CENTER OF EXPERTISE AND DESIGN CENTER: HOMEPAGE

APPENDIX H.2
U.S. ARMY, HUNTSVILLE - ORDNANCE AND EXPLOSIVES MANDATORY CENTER OF EXPERTISE AND DESIGN CENTER: INDEX OF DATA ITEM DESCRIPTION

APPENDIX H.3
U.S. ARMY, HUNTSVILLE - ORDNANCE AND EXPLOSIVES MANDATORY CENTER OF EXPERTISE AND DESIGN CENTER: REGULATIONS, GUIDANCE, AND PROCEDURES

APPENDIX I
UXO DETECTION METHODS

DoD, APRIL 1998

Table 1 No "Silver Bullet" – Alternative Technologies All Have Strengths and Limitation				
Alternative Technologies	**Availability**	**Overall Effectiveness**	**Cost (to purchase, use and maintain)**	**Comments**
Detection/Remediation of Surface UXO				
Electro-Optical/Thermal Imaging	+	O	O	A surface detection system that can provide wide area search for UXO. Best concept is combined active laser system with passive IR. Can detect ferrous and non-ferrous objects, and provides high resolution data on shape and orientation. Has difficulty in foliage. EO needs direct line of sight to UXO.
Synthetic Aperture Radar	O	O	-	Primarily a surface detection system, suitable for surveying very large areas (and detecting large objects and providing 2-D images). Best suited for detecting minefield areas rather than for locating individual ordnance. Best against metal objects.
Biological Detectors (including artificial)	(dogs) + (artificial dogs) -	+	+	A surface detection system, perhaps useful against shallow-depth UXO, but primarily for mines and explosives; include trained canines or surrogates. Best for identifying individual UXO: does not measure depth, size, or orientation.
Detection/Remediation of Near-Surface UXO				
Thermal Neutron Activation	+	O	-	Detection is limited by background signal; provides x-ray resolution. The main problem is discrimination between photons from Silicon-29 and Nitrogen-14; nitrogen contained in the soil may also contribute. Other sources of background include pulse pile-up and cosmic rays. Neutron absorption in boron, rare earth elements or rich soils can also be a problem. System performance may be quite good for large shallow ordnance, but detection of all relevant size/depths will only be fair.
Fast Neutron Activation	O	-	-	May provide size, depth, and orientation information, but suffers from severe attenuation and poor discrimination of UXO from carbon, hydrogen and nitrogen and oxygen.
Ground Penetrating Radar	O	O	O	Provides depth, size, and orientation data; useful signatures and resolution to depths of about 1 foot. Greater depth possible at 5 GHz or lower, but requires increasingly sophisticated processing. Very high false alarm rates. Corrected Pd often statistically indistinguishable from 0. Best on roads or in homogeneous media.
Trace Chemical Detectors	O	O	+	A subsurface detection system that senses a chemical signature left by UXO (e.g., mass spectrometry, GC-ECD, IMS, dogs, etc.). Provides no depth, size, or orientation

Table 1 No "Silver Bullet" – Alternative Technologies All Have Strengths and Limitation				
Alternative Technologies	**Availability**	**Overall Effectiveness**	**Cost (to purchase, use and maintain)**	**Comments**
				information and may have very high false alarms due to local environmental conditions.

Table 1 No "Silver Bullet" – Alternative Technologies All Have Strengths and Limitation				
Alternative Technologies	**Availability**	**Overall Effectiveness**	**Cost (to purchase, use and maintain)**	**Comments**
Hyperspectral Imaging	+	O	-	It is primarily used to detect changes in surface soil properties due to a mine burial. For newly emplaced mines on road beds, this technique should be very good, but is not likely to work in foliage and fields. Can detect ferrous and non-ferrous objects.
Bulk Chemical Detectors	O	O	O	Includes chemical interaction with x-rays and Nuclear Quadrupole Resonance (NQR). In principle, can measure size, orientation and depth; severely limited by soil attenuation. NQR may achieve very low false alarm rates, but ineffective against radio frequency (RF) shielded explosives.
Detection/Remediation of Deeply Buried UXO (>10 feet)				
Passive Magnetometers	+	+	-	Most widely used substance detection system today; capable for near-surface and deep objects; discrimination better deep given highly cluttered environment near the surface (except in highly magnetic soils). Fair to poor capability for discrimination, very good depth accuracy, fair to good information on size. Orientation of the magnetic moment can be determined, but this does not map one-to one with the ordnance orientation performance degrades significantly in highly magnetic soils. This can be improved by magnetic gradiometry. Limited to ferrous materials; since mine-like targets not typical deeply buried, not a significant limitation. Biggest cost factor is wide area survey
Elecromagnetic Induction Magnetometers	+	+	-	The drop off in the transmit to receive field is between $1/d^3$ and $1/d^6$ depending on the size of the transmit coil and the depth of the UXO. There is potential to discriminate clusters of UXO from a single item (early in the research at this point). Limited to good electrical conductors (brass, iron, etc.); since mine-like targets not typically deeply buried, not a significant limitation. Biggest cost factor is wide area survey.
Seismic/ Acoustic	O	O	O	Inherently poor spatial resolution; best suited for locating large objects at depths greater than 10 feet in variety of environmental conditions; little capability to characterize depth, size, and orientation.
Signal Processing and Data Fusion				
Signal Processing	-	+	O	Future sensors will incorporate Automatic Target Recognition (ATR). ATR software is

Table 1 No "Silver Bullet" – Alternative Technologies All Have Strengths and Limitation				
Alternative Technologies	**Availability**	**Overall Effectiveness**	**Cost (to purchase, use and maintain)**	**Comments**
				emerging which can interpret subtle signatures, where humans are not as effective.
Data Fusion	-	+	O	ATR software is also being used to fuse information from multiple sensors. Such ATR software will be used to augment human performance.
Real-Time Differential GPS	O	+	-	Use of Differential Global Positioning System (DGPS) will enable much more effective UXO remediation operations spanning wide area search through remediation. The UXO community is beginning to use this technology. The technique needs a lot of expansion. Fieldwork indicates that DGPS with real time kinetic (RTK) corrections is required for resolution sufficient to investigate sensor fusion approaches.
New Concepts				
Acousto-Electronmagnetic Sensor	O	Unknown until further research	?	Stimulation of UXO with surface acoustic wave; sensing of the UXO vibrations (down to 20 microns) using 10 GHz radar.
Ultrasonic Stimulation with Chemical Detection	-	Unknown until further research	?	Stimulation of UXO with ultrasonic radiation and detection of chemical particulates/vapor emitted from UXO (concept uses particle sampler with Micro-Electro Mechanical System [MEMS] actuator).

Key: + high feasibility/value/lowest cost; O – moderate; - marginal

APPENDIX J
SUPPLEMENTAL
REFERENCE DOCUMENTS

- APPENDIX J.1 — A STRATEGY FOR ACHIEVING COST EFFECTIVE CLOSURE OF OPEN BURNING/OPEN DETONATION UNITS (MINOR, ET AL., DECEMBER 1995)
- APPENDIX J.2 — EPA REACHES SETTLEMENT ON "CAMU" RULE (USEPA, FEBRUARY 2000)
- APPENDIX J.3 — FIELD SAMPLING AND SELECTING ONSITE ANALYTICAL METHODS FOR EXPLOSIVES IN SOIL (USEPA, NOVEMBER 1996b)
- APPENDIX J.4 — RISK-BASED CLEAN CLOSURE GUIDANCE (USEPA, MARCH 1998)
- APPENDIX J.5 — SUMMARY OF RCRA CLOSURE REGULATIONS FOR OB/OD UNITS (U.S. ARMY, SEPTEMBER 1998)
- APPENDIX J.6 — RCRA CLOSURE TRAINING DOCUMENT (USEPA, JULY 1997)
- APPENDIX J.7 — NATURAL ATTENUATION GUIDANCE (USEPA, APRIL 1999)
- APPENDIX J.8 — MANAGEMENT OF REMEDIAL WASTE GUIDANCE (USEPA, OCTOBER 1998c)
- APPENDIX J.9 — RCRA CLOSURE/POST-CLOSURE AMENDMENT FACT SHEET (USEPA, OCTOBER 1998b)
- APPENDIX J.10 — FACT SHEET: ALTERNATIVE MECHANISMS FOR CLOSURE AND POST-CLOSURE (U.S. ARMY, UNDATED)
- APPENDIX J.11 — REMEDIATION TECHNOLOGY INFORMATION RESOURCES

APPENDIX J.12 — NAVAL SURFACE WARFARE CENTER INDIAN HEAD DIVISION'S EXPLOSIVE DECONTAMINATION EXPERIENCE (U.S. NAVY UNDATED)

APPENDIX J.13 — DRAFT STANDARD SCREENING-LEVEL MEASUES OF ECOTOXICOLOGICAL EFFECTS (USACHPPM, OCTOBER 2000).

APPENDIX J.1
A STRATEGY FOR ACHIEVING COST EFFECTIVE CLOSURE OF OPEN BURNING/OPEN DETONATION UNITS
(MINOR, ET AL., DECEMBER 1995)

A Strategy For Achieving Cost Effective Closure Of Open Burning/Open Detonation Units .

C. Minor[1], Dames & Moore, E. Goller[2], Dames & Moore, A. Stahl[3], Dames & Moore, J. Anderson[2], Dames & Moore, Capt. D. Lawrence[4], USAF, C. Thomas[5], USAF

Introduction.

Many government installations currently operate or have historically operated Open Burning/Open Detonation (OB/OD) Units for treatment and disposal of non-serviceable munitions and ordnance. Non-serviceable munitions and ordnance are considered reactive hazardous waste under the Resource Conservation and Recovery Act (RCRA). Treatment of reactive hazardous waste by OB/OD is regulated by 40 CFR Part 264 Subpart X and must be included in the facility's Part B Permit. Facilities which find they no are longer required to utilize their OB/OD Units are faced with the challenge of cost effectively closing the units in accordance with RCRA requirements. The total costs associated with closure of OD/OD Units can vary tremendously depending upon nature and extent of contamination, the chosen closure strategy and the selected management approach.

Developing and implementing a strategy for achieving clean closure rather than closing as a landfill with contamination remaining in place, can minimize or eliminate the requirements for post closure care. Much of the total closure costs are derived from the post closure care requirements which include construction of a RCRA cap, installation of groundwater monitoring wells, and 30 years of monitoring and maintenance. These requirements apply unless it can be demonstrated that the closure procedures met the standards for closure by removal and decontamination (clean closure). With careful planning and foresight, OB/OD Units are amenable to clean closure eliminating the need for costly post closure care.

Achieving clean closure of OB/OD Units requires careful consideration and selection of the closure plan approach, skillful negotiation with regulators, and a management approach which includes a willingness to consider greater initial monetary investment in order to reduce total long term expenditures. Application issues of concern which deserve consideration when developing a clean closure strategy are discussed below.

Identification of contaminants of concern related to OB/OD activities

Contaminants of concern (CoCs) that accumulate in various media around OB/OD Units generally include metals, explosives, and petroleum hydrocarbons. These CoCs are typically generated from three sources: Residuals remaining as combustion by-products after completion of treatment operations, partially treated waste ejected prematurely from the treatment unit, and/or spilled or residual compounds from the treatment catalyst.

Identification of potential CoCs for use as indicators for action levels for OB/OD Unit closure is typically performed by examining the inventory of waste treated, methods of treatment, and any available historical sampling data. Additional sampling and analysis of various media at the previously operated OB/OD Unit can also be performed to further reduce the CoC list.

The Explosive Ordnance Disposal (EOD) Fight at Elmendorf Air Force Base (EAFB) has treated non-serviceable munitions and unstable ordnance by OB/OD for more than four decades. Residual chemical constituents identified in soil at the EAFB OB/OD Range include: metals (including lead and barium), explosives (such as HMX, RDX, 2,4,6-Trinitrotoluene and 2,4-Dinitrotoluene), nitrate/nitrite, and Total Petroleum Hydrocarbons (TPH). Metals are found as discrete particles or leachate accumulation in soil from munitions and ordnance casings and from emissions form flare and smoke pot destruction.

Explosives and nitrate/nitrite are primarily from untreated waste, however some may be degradation compounds from treated waste. TPH compounds are from spilled or residual petroleum product (usually JP-4 or JP-8) used as an igniting agent for open burning operations.

Negotiation of performance-based closure standards in lieu of soil cleanup levels

Depending upon specific site characteristics, it may be possible to negotiate the use of performance-based closure standards to demonstrate clean closure in lieu of the traditional method of demonstrating that the remaining soils contain constituents of concern at concentrations below specified cleanup levels. This approach offers the opportunity for substantial cost savings by:

- Simplifying closure plan implementation;
- Eliminating need for confirmation soil sampling and analytical testing; and
- Minimizing the potential for multiple mobilizations of cleanup contractors.

Closure of the Emergency Permitted OB/OD Unit at EAFB provides an example where this approach was successfully implemented. During discussions with the Environmental Protection Agency (EPA) regarding OB/OD Unit closure procedures, Dames & Moore on behalf of EAFB was able to negotiate the use of performance based standards to demonstrate clean closure of Emergency OB/OD land-based units. The negotiated performance-based standard included removal of the uppermost six to twelve inches of soil from the surface area of the crater. Upon demonstration that the performance-based standard had been achieved, the Emergency OB/OD Unit was considered clean closed.

Negotiation of acceptable soil cleanup levels if performance-based standards are deemed unacceptable

If the regulating agency will not agree to the use of performance-based standards, there is still the opportunity to negotiate manually acceptable cleanup action levels. It is often possible to demonstrate that the use of less restrictive cleanup action levels will still provide adequate protection to human health and the environment. Risk assessment data and/or demonstration of naturally occurring elevated levels of the constituent of concern can help to justify less restrictive cleanup levels. This approach offers the opportunity to achieve cost savings by:

- Ensuring that cleanup levels are achievable given the site conditions;
- Minimizing the quantity of soil required to be removed and disposed; and
- Reducing potential future liability by removing contaminated media with unacceptable risk.

Partial closure of the OB/OD Unit at Luke Air Force Base (LAFB) Barry M. Goldwater Air Force Range (BMGR) provides an example where this approach was successfully implemented. The action levels for seven of the eight RCRA metals were consistent with the health-based concentrations of the Preliminary Remediation Goals (PRGs) published by EPA Region IX on August 1, 1995. However, an alternative action level for arsenic was identified through an assessment of background arsenic levels in the vicinity of the OB/OD Unit at the BMGR. This modified action level was proposed because Arizona soils typically have background arsenic concentrations in excess of health-based carcinogenic screening levels.

Selection of cost effective decontamination procedures for structures and equipment to achieve a "clean debris surface"

The majority of historical OB/OD Units utilized some form of concrete and/or metal equipment and structures including burn pans, burn beds, burn boxes, burn kettles, burning furnaces, and protective barriers. These materials can either be disposed as hazardous waste or sufficiently decontaminated to be considered no longer hazardous. Decontamination of equipment and structures according to the Alternative Treatment Standards for Hazardous Debris as described in Table 1 of 40 CFR Part 268.45 is generally sufficient to demonstrate a "clean debris surface" has been achieved. Table 1 provides a range of acceptable decontamination alternatives for a variety of media. Selection of an appropriate decontamination method in lieu of disposing of OB/OD Unit equipment and structures offers the following potential cost savings by:

- Reducing costly hazardous waste transportation and disposal;
- Reducing potential future liability associated with landfilling hazardous waste; and
- Increasing the opportunity for future beneficial reuse or recycling of the equipment or structure.

The Emergency OB/OD Unit burn pan at EAFB were effectively decontaminated using *"High Pressure Steam and Water Sprays"*. A "clean debris surface" was achieved and the burn pan was retained on site for future beneficial use as a storage or garbage container.

Alleviating clean closure equivalency demonstration requirements of 40 CFR 270

In accordance with 40 CFR 270.1(c)(5), "owners/operators of surface impoundments, land treatment units, and waste piles closing by removal or decontamination under part 265 standards must obtain a post-closure permit unless they can demonstrate to the Regional Administrator that the closure met the standards for closure by removal or decontamination in 40 CFR 264.228, 264.280(e), or 264.258 respectively." Depending on the nature of OB/OD Unit activities conducted at the site, land treatment units or waste piles may require closure under RCRA. These units are potentially subject to the clean closure equivalency demonstration requirements described above.

EPA has the authority to require an equivalency demonstration where is deems it appropriate for any reason. However, when closure has been accomplished in accordance with a closure plan which was subject to public comment and subsequently approved by EPA or an authorized State agency it can generally be demonstrated that an equivalency determination would be essentially redundant and would not contribute further to protection of human health and the environment. Under such conditions, EPA will generally not require additional documentation and submittal of an equivalency determination. Alleviating the need for a clean closure equivalency demonstration provides the opportunity for cost savings by:

- Reducing soil and groundwater investigation activities;
- Reducing compilation of investigation data and report preparation; and
- Reducing work scope exposed to subjective interpretation and decision-making by the site owner and regulatory authorities.

Cost benefit analysis of clean closure versus closure as a landfill with contamination remaining in place

The cost of closure of OB/OD Units is primarily a function of the cost of waste disposal. The primary closure options include: clean closure using the "Removal/Disposal" approach to waste management, and landfill closure using the "Containment" approach. To reduce the cost of closure to a minimum requires selection of the least expensive alternative.

Clean closure of a RCRA permitted treatment facility relieves the owner of potential future liability for the site within a short period of time following closure. This involves the removal, decontamination and disposal of all media associated with the OB/OD Unit containing CoCs in concentrations above the action levels. Key clean closure cost analysis issues include:

- Detailed characterization of the former treatment site to define the extent of the impact of CoC to various media may be required;

- Potential generation of a relatively large one time volume of waste requiring characterization, transportation and disposal; and

- Significant negotiation with regulators to define the concentrations of CoCs that may be left behind at the former treatment site may be required.

The cost for off-site disposal of wastes generated from an OB/OD Unit closure is usually the largest cost driver in clean closure. The greater the proportion of non-hazardous waste verses hazardous waste, the more attractive the clean closure approach becomes.

Landfill closure of a RCRA permitted facility entails an additional 30 year commitment of the treatment facility owner. The "Containment" approach requires management of all contaminated media at the former treatment facility in a manner such that no contaminant migration will occur. The standards method of accomplishing this objective is to construct a RCRA multi-media cap over the consolidated contaminated media at the site and installing groundwater monitoring wells. The site owner is obligated to provide cap maintenance, surveillance and security at the site to assure that none of the CoCs migrate to groundwater in concentrations above the water quality protection standards. Key landfill closure cost analysis issues include:

- Detailed characterization of the former treatment site to define the extent of CoC contamination may be required;
- Design, construction and maintenance of a RCRA multi-media cap and groundwater monitoring wells will be required; and
- Significant negotiation with regulators to define the monitoring and maintenance requirements for inclusion in the post closure permit for the former treatment site may be required.

The RCRA multi-media cap construction, annual operation, maintenance and environmental monitoring effort are the largest cost drivers in landfill closure. As the cost associated with these efforts rise, the landfill closure approach becomes less attractive.

A valuable tool in evaluating the costs of clean closure verses landfill closure is a present worth or net present value analysis. Clean closure total costs are accumulated in one to two years. Landfill closure costs include a substantial initial investment followed by 30 years of operation and maintenance costs. Converting the total costs for both closure alternatives to net present value facilitates a simple cost comparison.

Clean closure and landfill closure net present value total costs can be within 20% of each other. Some simple guidelines are presented below for consideration in evaluation of clean closure verses landfill closure cost comparisons.

- Clean closure of OB/OD Units is likely to be cost effective due to the typically low concentrations of regulated residual contaminants in accumulation areas.
- Clean closure is likely to be the cost effective closure alternative when off-site disposal costs are less than 25% of the total cost for the remedy.
- Landfill closure is likely to be the preferred approach if forecasted cumulative annual operations and maintenance net present value costs are less than 35% of the net present value cost of the RCRA cap design and construction.

Conclusion

OB/OD Units undergoing closure at the EAFB and LAFB as described above offer examples of the challenges and benefits associated with achieving clean closure. In most cases, the additional planning, agency negotiation, and initial monetary investment which may be required to develop and implement a strategy of clean closure is well worth the effort in terms of total cost savings and protection of human health and the environment.

1. Dames & Moore, 1750 SW Harbor Way, Portland, Oregon (503) 228-7688
2. Dames & Moore, 5600 B Street, Anchorage, Alaska (907) 562-3366
3. Dames & Moore, 7500 N. Dreamy Draw Drive, Phoenix, Arizona (602) 861-7474
4. U.S. Air Force, 3 CES/CEUC, Elmendorf AFB, Alaska (907) 552-4157
5. U.S. Air Force, 56 CES/CEVN, Luke AFB, Phoenix, Arizona (602) 856-3823

APPENDIX J.2
EPA REACHES SETTLEMENT ON "CAMU" RULE (USEPA, FEBRUARY 2000)

APPENDIX J.3
FIELD SAMPLING AND SELECTING ONSITE ANALYTICAL METHODS FOR EXPLOSIVES IN SOIL
(USEPA, NOVEMBER 1996b)

APPENDIX J.4
RISK-BASED CLEAN CLOSURE GUIDANCE
(USEPA, MARCH 1998)

APPENDIX J.5
SUMMARY OF RCRA CLOSURE REGULATIONS
FOR OB/OD UNITS
(U.S. ARMY, SEPTEMBER 1998)

SUMMARY OF OB/OD CLOSURE REQUIREMENTS

Interim status OB/OD units must follow the closure requirements at 40 CFR 265.381 (closure of 'Subpart P' Thermal Treatment units) and 40 CFR 265.110-265.120 (general Closure and Post-Closure requirements for interim status units). If the interim status OB/OD unit cannot "clean close" (i.e., remove all hazardous waste from the unit), then the OB/OD must "close as a landfill" meaning that the closure requirements of 265.310 (closure of 'Subpart N' Landfills) must also be followed. These landfill closure requirements mandate groundwater monitoring requirements under 265.90-265.94 ('Subpart F' Ground-Water Monitoring).

Permitted OB/OD units have very similar closure requirements although the numbers are different. Permitted OB /OD units must follow the closure requirements at 40 CFR 264.601& 603 (environmental performance standards and post-closure of 'Subpart X' Miscellaneous units) and 40 CFR 264.110-264.120 (general Closure and Post-Closure requirements for interim status units). If the interim status OB/OD unit cannot "clean close" (i.e., remove all hazardous waste from the unit), then the OB/OD must "close as a landfill" meaning that the closure requirements of 264.310 (closure of 'Subpart N' Landfills) must also be followed. These landfill closure requirements mandate groundwater monitoring requirements under 264.90-265.99 ('Subpart F' Ground-Water Monitoring).

What follows is a summary of each of these sections. For brevity, only the interim status requirements are summarized. Note that the major differences between interim status and permitted closure involve the differences between Subpart P (interim status) and Subpart X (permitted) and that the ground-water monitoring requirements for permitted units contains several additional sections.

Subpart P – Thermal Treatment Closure (40 CFR 265.381)

This section states: "At closure, the owner or operator must remove all hazardous waste and hazardous waste residues (including, but not limited to, ash) from the thermal treatment process or equipment."

Subpart G – Closure and Post-Closure (40 CFR 265.110-265.120)

CLOSURE:

265.110 – Applicability.

265.111-.115 (closure) apply to all hazardous waste TSD facilities.

265.116-.120 (post-closure) apply to hazardous waste disposal facilities, waste piles and surface impoundment's, tank systems, and containment buildings unless they "clean close."

265.111 – Closure performance standards. Closure the facility to

a. minimize the need for maintenance
b. control/minimize post-closure escape of hazardous waste, hazardous constituents, to the ground, surface wasters or air.
c. comply with closure req'ts for specific type of unit involved.

265.112 – Closure Plan

a. Need written plan by May 1981 or w/in 6 months of RCRA applicability.
b. Content of plan: describe how each unit will be closed in accordance with 265.111; how final closure will be conducted, estimate the maximum inventory of hazardous wastes ever onsite; detailed description of methods for removing, transporting, treating, storing ,or disposing of all hazardous waste; detailed description of steps needed to remove or decontaminate all hazardous waste residues and contaminated equipment and soils; a detailed description of other necessary activities to satisfy 265.111 including, ground-water monitoring, leachate collections, and runoff control; a schedule for closure for each unit and for final closure of the facility; and an estimate of the expected year of final closure (if trust fund).
c. Amendment of plan: If Closure Plan is not approved – can modify at any time prior to closure notification. If Closure Plan is approved, must submit written request. Must amend the closure plan when changes in operating plans or facility design affect the closure plan (notify within 60 days prior to change), there is a change in the expected year of closure if applicable, an unexpected event during

closure requires a modification (notify within 30 days after event), or an unexpected event not during closure requires a modification (notify within 60 days).

d. Notification of beginning/ready for final closure:
   If Closure Plan is not approved
      +clean closure = no notification required for OB/OD
      +closing as a landfill = submit plan 180 days prior to date "expect to begin closure." (i.e., 30 days after receipt of known last waste or 1 year after receipt of last waste if reasonable possibility receive additional wastes. Extension possible.)
   If Closure Plan is approved
      + clean closure =no notification required for OB/OD
      +closing as a landfill = 60 days notice prior to date "expect to begin closure."

   Public comment will be allowed 30 days after notice. Public Meeting may be requested. EPA must approve, disapprove, or modify plan within 90 days of its receipt. (If disapproved, owners must modify w/in 30 days, EPA must approve/modify w/in 60.)

e. Owner can remove hazardous wastes and decontaminate/dismantle equipment with an approved closure plan at any time before or after notification. [For example, an owner may decontaminate, dismantle, and dispose of burn pans or other equipment at an OB unit without these activities triggering the closure notification requirements].

265.113-Time allowed for closure.

a. (timeline for removing hazardous wastes).
b. Closure timeline: If Closure Plan is not approved, within 180 days after receiving the final volume of hazardous waste OR upon approval of the closure plan, whichever is later. If Closure Plan is approved , within 180 days after receiving the final volume of hazardous waste. Extensions can be granted.
c. Timelines for extensions.
d. Req'ts if unit will receive non-hazardous waste
e. Req'ts for certain surface impoundments.

265.114 –Disposal or decontamination of equipment & soils. All contaminated equipment, structures, and soil must be property disposed of, or decontaminated. RCRA generator requirement may be applicable during these activities.

265.115 – Certification of closure. Within 60 days of closure completion, the owner and an independent registered professional engineer must sign a certification stating that closure activities were conducted in accordance with the approved closure plan and submit it to the regulator.

265.116. – Survey plat. If the OB/OD is closed as a landfill, a survey plat must be submitted to the local zoning authority and must contain a deed notation concerning restriction of disturbance of hazardous waste.

POST-CLOSURE:

265.117—Post-closure care and use of property.

a. It continues for 30 years after completion of closure, although this period can be shortened or extended. It consists of: monitoring & reporting under unit specific req'ts (i.e., per subparts F-groundwater, K-surface imp., L-waste pile, M-land treatment , and N- landfills); maintenance and monitoring of containment systems under unit specific req'ts.
b. Security requirements at 265.14 may also be req'd.
c. Post-closure use of property where hazardous wastes remain must never disturb the integrity of the final cover, line, containment system or monitoring system (unless site-specific regulator allowance).

265.118 –Post-Closure Plan.

a. Hazardous waste disposal facilities need a Post-Closure Plan.
b. Must be given to regulator, upon request.

c. Contents: description of planned monitoring activities & frequencies to comply with unit specific req'ts; a description of planned maintenance activities and frequencies to ensure the integrity of the cap and final cover or other containment systems and the function of monitoring equipment; name, address, and phone number of POC.
d. Amendment process and deadlines.
e. Amendment deadlines.
f. Public comment provisions and timelines.
g. Modification of post-closure plan and length petition process.

265.119—Post-closure notices.

a. Within 60 days of closure certification, submit to the local zoning authority a record of the type, location, and quantify of hazardous wastes disposed. (To the best of his knowledge for wastes disposed prior to Jan 1981.
b. Record a notice in a deed that the land has been used to manage hazardous wastes and its use is restricted. The owner will need to submit a certification to the regulator stating that the deed notation has been recorded.
c. If a subsequent owner wishes to remove hazardous wastes, he must request a modification to the post-closure plan. The regulator may later approve removal of the deed restriction.

265.120 – Certification of completion. Within 60 days of closure completion, the owner and an independent registered professional engineer must sign a certification stating that post-closure activities were conducted in accordance with the approved post-closure plan and submit it to the regulator.

Subpart N – Landfill Closure (40 CFR 265. 310)

a. The owner must cover the landfill with a final cover designed and constructed to:
- minimize migration of liquids;
- require minimum maintenance;
- promote drainage &minimize erosion;
- accommodate settling; and
- have a permeability ≤permeability of any bottom liner system or natural subsoil present.

b. Comply with post-closure requirements in 265.117-120.
c. The owner must:
- maintain the integrity of final cover, including making repairs;
- maintain and monitor leak detection system in accordance with 264.301 and 265.304
- maintain and monitor the groundwater monitoring system and comply with applicable parts of subpart F;
- protect and maintain surveyed benchmarks used in 265.309.

Subpart F—Groundwater Monitoring (40 C.F.R. §§ 265.90-.94)

Note that groundwater monitoring requirements under Subpart F (40 CFR 264-permitted units) only apply to "regulated units." Regulated units are surface impoundments, waste piles, land treatment units, or landfills that receive hazardous waste after July 26, 1982. While the interim status provisions for groundwater monitoring under Subpart F (40 CFR 265 – interim status) do not use the term "regulated units" the section lists out the requirements only apply to surface impoundments, landfills, or land treatment units. (Waste piles have their own monitoring requirements in Subpart L).

265.90 -- Applicability .

a. Surface impoundments, landfills, and land treatment facilities must have a groundwater monitoring program that determines the facility's impact on the uppermost aquifer underlying the facility (unless (c) below).
b. The groundwater monitoring program must be carried out during the active life of the facility, (+ post-closure for disposal facilities) and meet the req'ts of 265.91-94 (unless (c) or (d) below).
c. All or part of the groundwater monitoring requirements can be waived if demonstrate that there is a low potential for migration of hazardous waste from the facility via the uppermost aquifer to water supply wells or to surface water.
d. Alternate groundwater monitoring indicator parameters are allowed.
e. Waivers for surface impoundments.

§ 265.91 Ground-water monitoring system

(a) A groundwater monitoring system must consist of monitoring wells sufficient to yield representative background samples that are not affected by the facility. The (at least 3) monitoring wells must be able to detect any statistically significant amounts of hazardous waste or constituents that migrate from the waste management area to the uppermost aquifer. Where physically impossible to install a well, an alternate hydraulically downgradient monitoring well location may be used.

(b) Separate monitoring systems for each waste management component of a facility are not required so long as the system can detect any discharge from the waste management area.

(c) All monitoring wells must be cased to ensure integrity of the boring hole.

§ 265.92 Sampling and analysis

(a) the owner must obtain and analyze samples according to a groundwater monitoring plan.

(b) The owner must determine the concentrations/values of parameters for groundwater including those for chloride, iron, manganese, phenols, sodium, sulfate, (⇐groundwater quality) pH, specific conductance, total organic carbon, and total organic halogen (⇐groundwater contamination indicators).

(c) Background concentrations or values for all specified parameters must be obtained quarterly for one year.

(d) Water-quality parameter levels must be analyzed annually after the first year; groundwater contamination parameters must be analyzed semiannually after the first year.

(e) Elevation of the groundwater surface at each monitoring well must be determined each time a sample is obtained.

§ 265.93 Preparation, evaluation, and response

(a) Within one year after effective date of regs, owners must prepare outlines of groundwater quality assessment programs which describe monitoring programs capable of determining whether waste/constituents have entered the groundwater, the rate and extent of this migration, and the concentrations of waste/constituents present.

(b) For groundwater quality indicator parameters, the owner must calculate the mean and variance for each well monitored.

(c) If upgradient wells show a significant change in pH, the owners must submit this information. If the downgradient wells show such a change, the owners must obtain additional samples from those wells showing the significant difference and re-analyze them to rule out laboratory error.

(d) If the initial results were accurate, the owner has 7 days to notify the Administrator in writing, and 15 days after this notification to develop and submit a plan to assess groundwater quality. If no groundwater contamination is found, the original monitoring program may be reinstated with written notice to the Administrator. If contamination is found, determinations of the extent, etc of contamination must be made through final closure of the facility.

(e-f) Any groundwater quality assessment initiated prior to final closure must be completed and reported in accordance with § 265.93(c)(5). Monitoring wells must e maintained in locations that allow conditions of this subpart to be satisfied.

§ 265.94 Recordkeeping and reporting

(a) Unless groundwater is monitored, owners must
-keep records of analyses required and surface elevation measured throughout the active life of the facility, and , for disposal facilities, throughout the post-closure care period as well.
-report groundwater monitoring information to the Administrator;

(b) If groundwater is monitored to satisfy § 265.93(d)(4), the owner must keep records of the analyses and evaluations throughout active facility life and, for disposal facilities, throughout post-closure care period as well, and must submit annual (by March 1 following each calendar year) reports to the Administrator containing results of the groundwater quality assessment program.

APPENDIX J.6
RCRA CLOSURE TRAINING DOCUMENT
(USEPA, JULY 1997)

APPENDIX J.7
NATURAL ATTENUATION GUIDANCE
(USEPA, APRIL 1999)

APPENDIX J.8
MANAGEMENT OF REMEDIAL WASTE GUIDANCE
(USEPA, OCTOBER 1998c)

APPENDIX J.9
RCRA CLOSURE/POST-CLOSURE
AMENDMENT FACT SHEET
(USEPA, OCTOBER 1998b)

APPENDIX J.10
FACT SHEET: ALTERNATIVE MECHANISMS FOR CLOSURE AND POST-CLOSURE
(U.S. ARMY, UNDATED)

APPENDIX J.11
REMEDIATION TECHNOLOGY INFORMATION RESOURCES

http://aec.army.mil/prod/usaec/et/restor/restor.htm

APPENDIX J.12
NAVAL SURFACE WARFARE CENTER
INDIAN HEAD DIVISION'S
EXPLOSIVE DECONTAMINATION EXPERIENCE
(U.S. NAVY, UNDATED)

APPENDIX J.13

DRAFT STANDARD SCREENING-LEVEL MEASURES OF ECOTOXICOLOGICAL EFFECTS (USACHPPM, OCTOBER 2000)